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ABSTRACT

Designed for individual study and nonformal classroom instruction, this Navy training manual provides subject matter that relates to the occupational standards of the construction mechanic rating. Each chapter includes line drawings, diagrams, and photos illustrating the subject matter. Subjects covered include the following: preparation for advancement, principles and construction of internal combustion engines, fuel systems, cooling and lubricating systems, automotive electricity, automotive power trains, automotive chassis and bodies, brakes, construction equipment, and maintenance. Appended are sections on the metric system, automotive equipment inspection guide, and construction equipment inspection guide. A nonresident career course outline concludes the manual. (CT)

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CONSTRUCTION MECHANIC 3&2

NAVAL EDUCATION AND TRAINING COMMAND
RATE TRAINING MANUAL AND NONRESIDENT CAREER COURSE

NAVEDTRA 10644-G

CE 020 670

Although the words "he", "him", and "his", are used sparingly in this manual to enhance communication, they are not intended to be gender driven nor to affront or discriminate against anyone reading *Construction Mechanic 3 & 2*, NAVEDTRA 10644-G.

PREFACE

The ultimate purpose of training Naval personnel is to produce a combatant Navy which can insure victory at sea. A consequence of the quality of training given them is their superior state of readiness. Its result is a victorious Navy.

This Rate Training Manual and Nonresident Career Course (RTM/NRCC) form a self-study package that will enable candidates for advancement to Construction Mechanic Third Class and Construction Mechanic Second Class to fulfill the requirements of their rating. Among these requirements are the abilities to perform tasks involved in the maintenance, repair, and overhaul of automotive, materials-handling, and construction equipment.

Designed for individual study and not formal classroom instruction, the RTM provides subject matter that relates directly to the occupational standards of the Construction Mechanic rating. The NRCC provides a way of satisfying the requirements for completing the RTM. Assignments in the NRCC include learning objectives and supporting items designed to lead the student through the RTM.

This RTM/NRCC was prepared by the Naval Education and Training Program Development Center, Pensacola, Florida, for the Chief of Naval Education and Training. Technical assistance was provided by the Naval Facilities Engineering Command, Alexandria, Virginia, the Naval Construction Training Center, Port Hueneme, California, the Naval Construction Training Center, Gulfport, Mississippi, and the Civil Engineering Support Office, Port Hueneme, California.

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THE UNITED STATES NAVY

GUARDIAN OF OUR COUNTRY

The United States Navy is responsible for maintaining control of the sea and is a ready force on watch at home and overseas, capable of strong action to preserve the peace or of instant offensive action to win in war.

It is upon the maintenance of this control that our country's glorious future depends; the United States Navy exists to make it so.

WE SERVE WITH HONOR

Tradition, valor, and victory are the Navy's heritage from the past. To these may be added dedication, discipline, and vigilance as the watchwords of the present and the future.

At home or on distant stations we serve with pride, confident in the respect of our country, our shipmates, and our families.

Our responsibilities sober us; our adversities strengthen us.

Service to God and Country is our special privilege. We serve with honor.

THE FUTURE OF THE NAVY

The Navy will always employ new weapons, new techniques, and greater power to protect and defend the United States on the sea, under the sea, and in the air.

Now and in the future, control of the sea gives the United States her greatest advantage for the maintenance of peace and for victory in war.

Mobility, surprise, dispersal, and offensive power are the keynotes of the new Navy. The roots of the Navy lie in a strong belief in the future, in continued dedication to our tasks, and in reflection on our heritage from the past.

Never have our opportunities and our responsibilities been greater.

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CREDITS

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CHAPTER 1

PREPARATION FOR ADVANCEMENT

This training manual has been prepared for personnel of the regular Navy and the Naval Reserve, not only to assist them in advancement but also increase their knowledge in the various aspects of the Construction Mechanic rating. This manual is based on the minimum skill requirements that the Navy prescribes for its Construction Mechanics. Called occupational standards, these requirements are published in the *Manual of Navy Enlisted Manpower and Personnel Classifications and Occupational Standards,* NAVPERS 18068-D that lists the occupational standards for Construction Mechanics Third and Second Class. You will also see listed in NAVPERS 18068-D the skills and knowledges, called naval standards, that deal with naval organization, security, watchstanding, military conduct, military justice, and other military requirements.

Your responsibilities for the naval standards are about the same as those of petty officers in other ratings since every petty officer is a member of the Navy. However, your responsibilities for the occupational standards are special to your rating and directly related to the work you do as a Construction Mechanic (CM).

ENLISTED RATING STRUCTURE

The two main types of ratings in the present enlisted rating structure are general ratings and service ratings. Both Regular Navy and Naval Reserve personnel may hold these ratings.

GENERAL RATINGS identify broad occupational fields of related duties and functions. Some general ratings include service ratings; others do not.

SERVICE RATINGS identify specialties within a general rating. Although service ratings can exist at any petty officer level, they are most common at the PO3 and PO2 levels.

THE CONSTRUCTION MECHANIC RATING

The Construction Mechanic rating is a general rating at all levels. Construction Mechanics perform both administrative and technical tasks involved in maintenance, repair, and overhaul of automotive, materials/weight handling, and construction equipment.

The Construction Mechanic rating is a source of a number of NEC's (Navy Enlisted Classification Codes). NEC's reflect special knowledge and skills in certain ratings. The NEC Coding System is designed to facilitate management control over enlisted skills by accurately identifying billets and personnel. It also helps insure maximum skill utilization in distribution and detailing. The following NEC's may be earned by Construction Mechanics at certain grade levels by satisfactorily completing an applicable course of instruction at a Navy Class "C" school.

AUTOMATIC TRANSMISSION/HYDRAULIC SYSTEMS MECHANIC, CM-5801.—The skills and knowledge required for this NEC include troubleshooting, dismantling, repairing, and reassembling all types of automatic transmissions and torque converters; analyzing and correcting malfunctioning hydraulic pumps, controls and relief valves, and rams and cylinders; and repairing or replacing hydraulic lines and hoses.

AUTOMOTIVE ELECTRICAL TECHNICIAN, CM-5802.–Personnel with this NEC service, adjust, analyze, and repair automotive, materials handling, and construction equipment electrical systems.

STATIONARY DIESEL ENGINE MECHANIC, CM-5804.–Holders of this NEC must be able to maintain, repair, adjust, and overhaul stationary diesel engines with over 600 horsepower.

TYPES OF BILLETS

Most Construction Mechanic billets are located in Naval Mobile Construction Battalions (NMCB's), Construction Battalion Units (CBU's), Construction Battalion Maintenance Units (CBMU's), and Naval Construction Regiments (NCR's), which are engaged in overseas base construction. In addition, Construction Mechanics are assigned to a variety of billets in the Public Works Department of naval shore activities. A limited number of especially well-qualified Construction Mechanics, usually PO2, PO1, and CPO, are assigned as instructors at the CM School, Naval Construction Training Center (NCTC), Port Hueneme (California), or Gulfport (Mississippi).

Geographic Location

The Navy, as you know, maintains a large number of activities within the United States, mostly along the coastlines. As a CM, you may work at almost any one of them, either as a member of a unit of the Fleet operating at the station, or as a member of the station force itself.

In the Atlantic area you may be assigned duty in Spain, Italy, Newfoundland, or even Iceland or Greenland. You may work in Bermuda or at a number of other islands: Cuba, Puerto Rico, Trinidad, Barbados, Antigua, Turks Island, San Salvador, and so on. You may have the opportunity to winter over in Antarctica. Duty assignments may be had in Okinawa, Japan, Guam, the Philippines, Midway, and the Indian Ocean island of Diego Garcia.

Units of the Fleet

As a CM, you may not expect to be assigned to duty as a member of a ship's company. There is a possibility that you may be assigned to a Naval Amphibious Construction Battalion (PHIBCB), but you will most likely be assigned to an NMCB, or a detachment thereof, or to other activities related to the Fleet Construction Force such as a CBMU, CBU, regimental headquarters, or Construction Force headquarters. In an NMCB, you may expect to be in "A" company, which functions in a military capacity as a machinegun and rifle company. Known as the "equipment company," Construction Mechanics and Equipment Operators are usually assigned to "A" company.

The Public Works Department

When you are assigned to duty at a shore activity, either within the United States or overseas, you will most likely be assigned to the Public Works Department of the station. Most stations which have more than 100 people and 15 or 20 buildings have a Public Works Department (which administers and maintains public works and utilities), except that in some localities Public Works Centers have been established. These Centers perform the public works duties for a number of Navy activities in the vicinity of the Center. The Public Works Department is headed by the Public Works Officer, who is an officer of the Civil Engineer Corps. The organization and staffing of the Department vary considerably, depending on the size, location, and mission of the activity.

The larger Public Works Departments are generally divided into Administrative and Technical Divisions (Administrative, Engineering, Maintenance Control, and sometimes Housing) and Operating Divisions

(Maintenance, Utilities, and Transportation). The Operating Divisions are usually headed by a CEC officer who has the title Shops Engineer. Smaller stations might have only three divisions: Administrative, Engineering, and Shops. The Shops Division usually has a Transportation Branch.

Some Public Works Departments, particularly at small, isolated stations, may be staffed entirely by military personnel, but most Public Works Departments, both in the United States and overseas, are staffed largely by civilians. The Administrative and Technical Divisions (except for Maintenance Control) are mainly staffed with civilian employees classed as "GS," or "per annum," or "white collar". The Operating Divisions are mainly staffed with civilian employees classed as "wage board," or "per diem," or "blue collar". Supervisory blue collar employees have titles such as (in ascending order of responsiblity) snapper, head, leadingman, quarterman, and chief quarterman. Very large stations may also have master mechanics and foreman mechanics. At bases overseas, foreign nationals may be hired to work in the Public Works Department. They may be employed directly as a special category of civil servant, or they may be utilized as contract labor through the negotiation of a labor contract with the host government of the country involved.

Duty Within the U.S.

As stated before, if you are assigned to shore activity within the U.S. you will most likely be assigned to Public Works; but this is not always the case. In areas where there is a large stable supply of manpower, most of the transportation work is done by blue collar employees. Therefore, you may be assigned to the master-at-arms force, special services, the salvage yard, the commissary, or to any of a great variety of jobs.

Your chances of working at your trade are much better in areas where there is a relative shortage of manpower. In these areas, you may expect to be assigned to the Transportation Division or the Transportation Branch of the Shops Division. Some Public Works officers prefer to organize two separate lines of authority: one for civilians and one for the military personnel. Others prefer to integrate the civilians and military completely; in the latter case you may work beside a civilian and report to a CM1 who reports to a quarterman who, in turn, answers to the Shops Engineer who is an officer. There are some activities which are staffed completely by military personnel because the mission is highly classified; if you are assigned to a station of this type you may expect to work within your rating.

Duty at Overseas Bases

In general, you may expect to work in your trade if assigned to a shore activity outside the U.S. At smaller, relatively isolated stations the entire Public Works staff may be military personnel. At the larger activities you may expect to work with civilian employees from the U.S., both white collar and blue collar, and with foreign nationals.

THE NAVY ENLISTED ADVANCEMENT SYSTEM

Many of the rewards of Navy life are earned through the advancement system. The basic ideas behind the system have remained stable for many years, but specific portions may change rather rapidly. It is important that you know the system and follow changes carefully. BUPERS Notices 1418 will normally keep you up to date.

The normal system of advancement may be easier to understand if it is broken into two parts:

1. Those requirements that must be met before you may be considered for advancement.
2. Those factors that actually determine whether or not you will be advanced.

QUALIFYING FOR ADVANCEMENT

In general, to QUALIFY (be considered) for advancement, you must first:

1. Have a certain amount of time in pay-grade.

2. Demonstrate knowledge of material in your mandatory rate training manuals by achieving a suitable score on your command's test, by successfully completing the appropriate NRCC's or, in some cases, by successfully completing an appropriate Navy school.

3. Fulfill the Personnel Advancement Requirements (PAR) of your rating. (Described later in this chapter.)

4. Be recommended by your commanding officer.

5. For petty officer third and second candidates ONLY, demonstrate knowledge of military subjects by passing a locally administered MILITARY/LEADERSHIP examination based on the naval standards for advancement from NAVPERS 18068 series.

6. Demonstrate knowledge of the technical aspects of your rate by passing a Navy-wide advancement examination based on the occupational standards applicable to your rate from NAVPERS 18068 series (those standards listed at and below your rate level).

Figure 1-1 gives a detailed view of the requirements for advancement of active duty personnel; figure 1-2 gives this information for inactive duty personnel. Remember that the occupational standards can change. Check with your division officer or training officer to be sure that you have the most recent standards.

If you meet all of the above requirements satisfactorily, you become a member of the group from which advancements will be made.

WHO WILL BE ADVANCED?

Advancement is not automatic. Meeting all of the requirements makes you eligible, but does not guarantee your advancement. Some of the factors that determine which persons, out of all of those QUALIFIED, will actually be advanced in rate are the score made on the advancement examination, the length of time in service, the performance marks earned, and the number of vacancies being filled in a given rate.

If the number of vacancies in a given rate exceed the number of qualified personnel, then ALL of those qualified will be advanced. More often, the number of qualified people exceeds the vacancies. When this happens, the Navy uses a special procedure devised for advancing those who are BEST qualified. This procedure is based on combining three personnel evaulation systems:

Merit rating system (Annual evaluation and C.O. recommendation)

Personnel testing system (Advancement examination score—with some credit for passing previous advancement exams)

Longevity (seniority) system (Time in Rate and Time in Service)

Simply, credit is given for how much the individual has achieved in the three areas of performance, knowledge, and seniority. A composite, known as the final multiple score, is generated from these three factors. All of the candidates who have PASSED the examination from a given advancement population are then placed on one list. Based on the final multiple score, the person with the highest multiple score is ranked first, and so on, down to the person with the lowest multiple score. For candidates for E-4, E-5, and E-6, advancement authorizations are then issued, beginning at the top of the list, for the number of persons needed to fill the existing vacancies. Candidates for E-7, E-8, and E-9 whose final multiple scores are high enough will be designated PASS SELBD ELIG (pass Selection Board Eligible). This means that their names will be placed before the Chief, Senior Chief, and Master Chief Petty Officer Selection Boards, BUPERS boards charged with considering all so-designated eligible candidates for advancement to CPO, SCPO, and MCPO. Advancement authorizations for those being advanced to CPO, SCPO, and MCPO are issued by these boards.

Who, then, are the individuals who are advanced? Basically, they are the ones who achieved the MOST in preparing for advancement. They were not content to just qualify; they went the extra mile in their training, and through that training and their

REQUIREMENTS*	E1 to E2	E2 to E3	#E3 to E4	#E4 to E5	E5 to E6	##†E6 to E7	##†E7 to E8	##†E8 to E9
SERVICE	6 mos. service.	6 mos. as E-2.	6 mos. as E-3. 2 years time in service.	12 mos. as E-4. 3 years time in service.	24 mos. as E-5. 7 years time in service.	36 mos. as E-6. 10 years time in service.	36 mos. as E-7. 8 of 13 years time in service must be enlisted.	36 mos. as E-8. 10 of 16 years time in service must be enlisted.
SCHOOL	Recruit Training. (C.O. may advance up to 10% of graduating class.)		Class A for PR3, DT3, IS3, AME3, HM3, FTB3, MT3, MU3, EW3	Naval Justice School LN2		Navy School for AGC, MUC.††		
PERSONNEL ADVANCEMENT REQUIREMENT (PAR) NAVPERS 1414/4			Personnel Advancement Requirement (PAR) must be completed for advancement to E-4 through E-7.					
PERFORMANCE TEST			Specified ratings must complete applicable performance tests before taking examinations.					
ENLISTED PERFORMANCE EVALUATION	As used by CO when approving advancement.		Counts toward performance factor credit in advancement multiple.					
EXAMINATIONS**	Locally prepared tests.	See below.	Navywide examinations required for all PO advancements.			Navywide selection board.		
RATE TRAINING MANUAL (INCLUDING MILITARY REQUIREMENTS)		Required for E-3 and all PO advancements unless waived because of school completion, but need not be repeated if identical course has already been completed. See NAVEDTRA 10052 (current edition).					Nonresident career courses and recommended reading. See NAVEDTRA 10052 (current edition).	
AUTHORIZATION	Commanding Officer		NAVEDTRAPRODEVCEN					

*All advancements require commanding officer's recommendation.

†2 years obligated service required for E-7, E-8, and E-9.

#Military leadership exam required for E-4 and E-5.

**For E-2 to E-3, NAVEDTRAPRODEVCEN exams or locally prepared tests may be used.

††Waived for qualified EOD personnel.

##Advancement to E-7 will be 10 years TIS effective 1 January 1979; to E-8, 13 years TIS effective 1 November 1978; to E-9, 16 years TIS effective 1 November 1978.

Figure 1-1.—Active duty advancement requirements.

REQUIREMENTS*	E1 to E2	E2 to E3	E3 to E4	E4 to E5	E5 to E6	E6 to E7	E8	E9
TOTAL TIME IN GRADE	6 mos.	6 mos.	6 mos.	12 mos.	24 mos.	36 mos. with total 9 yrs service.	36 mos. with total 12 yrs service.	24 mos. with total 15 yrs service.
TOTAL TRAINING DUTY IN GRADE†	14 days	14 days	14 days	14 days	28 days	42 days	42 days	28 days
PERFORMANCE TESTS			Specified ratings must complete applicable performance tests before taking examination.					
DRILL PARTICIPATION	Satisfactory participation as a member of a drill unit in accordance with BUPERSINST 5400.42 series.							
PERSONNEL ADVANCEMENT REQUIREMENT (PAR) NAVPERS 1414/4			Personnel Advancement Requirements (PAR) NAVPERS 1414/4 must be completed for advancement to E4 through E7.					
RATE TRAINING MANUAL (INCLUDING MILITARY REQUIREMENTS)	Completion of applicable course or courses must be entered in service record.							
EXAMINATION	Standard Exam		Standard Exam required for all PO advancements. Also pass Military Leadership Exam for E4 and E5.				Standard Exam Selection Board.	
AUTHORIZATION	Commanding Officer		NAVEDTRAPRODEVCEN					

*Recommendation by commanding officer required for all advancements.
†Active duty periods may be substituted for training duty.

Figure 1-2.—Inactive duty advancement requirements.

work experience they developed greater skills, learned more, and accepted more responsiblity.

While it cannot guarantee that any one person will be advanced, the advancement system does guarantee that all persons within a particular rate will compete equally for the vacancies that exist.

HOW TO PREPARE FOR ADVANCEMENT

What must you do to prepare for advancement? You must study the occupational standards, work on the requirements stated in the PAR program, study the required rate training manuals, and the publications that are required for advancement in your rate. To prepare for advancement, you will need to be familiar with (1) the *Manual of Navy Enlisted Manpower and Personnel Classifications and Occupational Standards,* (2) the Personnel Advancement Requirement (PAR) Program, (3) the publication *Bibliography for Advancement Study,* NAVEDTRA 10052, and (4) applicable rate training manuals. The following paragraphs describe these publications and the PAR program and give you some practical suggestions on how to use them in preparing for advancement.

Section I of the *Manual of Enlisted Manpower and Personnel Classifications and Occupational Standards,* NAVPERS 18068-D with changes, contains the naval and occupational standards for advancement to each paygrade. Section II contains the Navy Enlisted Classifications (NEC's).

The NAVAL STANDARDS are requirements that apply to all ratings rather than any one particular rating. The OCCUPATIONAL STANDARDS are requirements that are directly related to the work of each rating. Both the naval standards and the occupational standards are divided into subject matter groups.

You are required to pass a Navy-wide military/leadership examination for E-4 or E-5, as appropriate, before you take the Navy-wide advancement examination. The military/leadership examinations are administered on a schedule determined by your commanding officer. Candidates are required to pass the applicable military/leadership examination only once at the E-4 and the E-5 levels. Each of these examinations consists of 100 questions based on information contained in *Military Requirements for Petty Officers 3 & 2* NAVEDTRA 10056 (current edition) and in other publications listed in *Bibliography for Advancement Study,* NAVEDTRA 10052 (current edition).

The Navy-wide advancement examinations for paygrades E-4 and E-5 contain 150 questions related to occupational areas of your rating.

If you are working for advancement to second class, remember that you may be examined on third class standards or Constructionman standards as well as on second class standards.

NAVPERS 18068-D is kept current by means of changes. The occupational standards for your rating which are covered in this training manual were current at the time the manual was printed, but by the time you study this manual, the standards for your rating may have been changed. Make sure the manual you refer to contains the latest changes.

PERSONNEL ADVANCEMENT REQUIREMENTS

The Personnel Advancement Requirement (PAR) (NAVPERS 1414/4) enables a command to evaluate the overall abilities of an individual in the day-to-day work situations and eliminates the need to complete a mandatory, lengthy, and detailed checkoff list.

The PAR for each rating is a pamphlet that lists the requirements for advancement to paygrades E-4 through E-7. It contains descriptive information, instructions for administration, special rating requirements, and advancement requirements.

Section I (Administration) contains the individual's length of service, time in rate, and a checkoff for the individual having passed the E-4/E-5 Military/Leadership Examination.

Section II (Formal School and Training) contains a checkoff entry for the individual having completed the military requirements rate training manual and the applicable rate training manual for the rating.

Section III (Occupation and Military Ability) is a checkoff list of task statements. Individuals are evaluated on their ability to perform the tasks. The evaluation may be based on ability in related areas, training received, or actual demonstration of the tasks.

PAR's do not exist for the E-8's and E-9's as there are other means of selection for advancement to these paygrades. The E-3 apprenticeships are so broad as to make the development of a single PAR impractical.

NAVEDTRA 10052

Bibliography for Advancement Study, NAVEDTRA 10052 is a very important publication for any enlisted person preparing for advancement. This bibliography lists required and recommended rate training manuals and other reference material to be used by personnel working for advancement.

NAVEDTRA 10052 is revised and issued once each year by the Chief of Naval Education and Training. Each revised edition is identified by a letter following the NAVEDTRA number. When using this publication, be SURE that you have the most recent edition.

If extensive changes in standards occur in any rating between the annual revisions of NAVEDTRA 10052, a supplementary list of study material may be issued in the form of a BUPERS Notice. When you are preparing for advancement, check to see whether changes have been made in the standards for your rating. If changes have been made, see if a BUPERS Notice has been issued to supplement NAVEDTRA 10052 for your rating.

The required and recommended references are listed by paygrade in NAVEDTRA 10052. If you are working for advancement to third class, study the material that is listed for third class. If you are working for advancement to second class, study the material that is listed for second class; but remember that you are also responsible for the references listed at the third class level and at the Constructionman level.

In NAVEDTRA 10052, you will notice that some rate training manuals are marked with an asterisk (*). Any manual marked in this way is MANDATORY—that is, it must be completed at the indicated rate level before you can be eligible to take the Navy-wide examination for advancement. Each mandatory manual may be completed by (1) passing the appropriate nonresident career course (NRCC) that is based on the mandatory rate training manual; (2) passing locally prepared tests based on the information given in the rate training manual; or (3) in some cases, successfully completing an appropriate naval school.

Do not overlook the section of NAVEDTRA 10052 which lists the required and recommended references relating to the naval standards for advancement. Personnel of ALL ratings must complete the mandatory military requirements training manual for the appropriate level before they are eligible to advance.

The references in NAVEDTRA 10052 which are recommended, but which are not mandatory, should also be studied carefully. ALL references listed in NAVEDTRA 10052 may be used as source material for the written examinations at the appropriate rate levels.

RATE TRAINING MANUALS

There are two general types of rate training manuals. RATING manuals, such as this one, are prepared for most enlisted ratings. A rating manual gives information that is directly related to the occupational standards of ONE rating. SUBJECT MATTER manuals or BASIC manuals give information that applies to more than one rating.

Rate training manuals are revised from time to time to keep them up to date technically. The revision of a rate training manual is identified by a letter following the NAVEDTRA number. You can tell whether any particular copy of a training manual is the latest edition by checking the NAVEDTRA number and the letter following this number in the most recent edition of *List of Training Manuals and Correspondence Courses,* NAVEDTRA 10061. NAVEDTRA 10061 is a catalog that lists all current training manuals and courses; you should find this catalog useful in planning your study program.

Each time a rate training manual is revised, it is brought into conformity with the official publications and directives on which it is based; but during the life of any edition, discrepancies between the manual and the official sources are almost certain to arise because of changes to the latter which are issued in the interim. In the performance of your duties, you should always refer to the appropriate official publication or directive. If the official source is listed in NAVEDTRA 10052, the Naval Education and Training Program Development Center uses it as a source of questions in preparing the Navy-wide examinations for advancement. In case of any discrepancy between the publications listed in NAVEDTRA 10052 for a given rate, the examination writers will either use the most recent material or avoid having questions on such sources.

Rate training manuals are designed to help you prepare for advancement. When you are preparing for advancement, the following suggestions may help you to make the best use of this manual and other Navy training publications:

1. Study the naval standards and the occupational standards for your rating before you study the training manual, and refer to the standards frequently as you study. Remember, you are studying the manual primarily in order to meet these standards.

2. Set up a regular study plan. It will probably be easier for you to stick to a schedule if you can plan to study at the same time each day. If possible, schedule your studying for a time of day when you will not have too many interruptions or distractions.

3. Before you begin to study any part of the manual intensively, become familiar with the entire book. Read the preface and the table of contents. Check through the index. Thumb through the book without any particular plan, looking at the illustrations and reading bits here and there as you see things that interest you.

4. Look at the training manual in more detail, to see how it is organized. Look at the table of contents again. Then, chapter by chapter, read the introduction, the headings, and the subheadings. This should give you a pretty clear picture of the scope and contents of the book. As you look through the book in this way, ask yourself some questions:

- What do I need to learn about this?
- What do I already know about this?
- How is this information related to information given in other chapters?
- How is this information related to the occupational standards?

5. When you have general idea of what is in the training manual and how it is organized, improve upon your knowledge by intensive study. In each study period, try to cover a complete unit–it may be a chapter, a section of a chapter, or a subsection. The amount of material that you can cover at one time will vary. If you know the subject well, or if the material is easy, you can cover quite a lot at one time. Difficult or unfamiliar material will require more study time.

6. In studying any one unit–chapter, section, or subsection–write down the questions that occur to you. Many people find it helpful to make a written outline of the unit as they study, or at least to write down the most important ideas.

7. As you study, relate the information in the training manual to the knowledge you already have. When you read about a process, a skill, or a situation, try to see how this information ties in with your own past experience.

8. When you have finished studying a unit, take time out to see what you have learned. Look back over your notes and questions. Maybe some of your questions have been

answered, but perhaps you still have some that are not answered. Without looking at the training manual, write down the main ideas that you have gotten from studying this unit. Don't just quote the book. If you can't give these ideas in your own words, the chances are that you have not really mastered the information.

9. Use nonresident career courses whenever you can. The courses are based on rate training manuals or on other appropriate texts. As mentioned before, completion of a mandatory rate training manual can be accomplished by passing a nonresident career course based on the rate training manual. You will probably find it helpful to take other courses, as well as those based on mandatory manuals. Taking a course helps you to master the information given in the training manual, and also helps you see how much you have learned.

10. Think of your future as you study rate training manuals. You are working for advancement to third class or second class right now, but some day you will be working toward higher rates. Anything extra that you can learn will help you both now and later.

SOURCES OF INFORMATION

Besides rate training manuals, NAVEDTRA 10052 lists official publications on which you may be examined. You should not only study the sections required, but should become as familiar as possible with all the publications you use.

One of the most useful things you can learn about a subject is how to find out more about it. No single publication can give you all the information you need to perform the duties of your rating. You should learn where to look for accurate, authoritative, up-to-date information on all subjects related to the naval requirements for advancement and the occupational standards of your rating.

PUBLICATIONS YOU SHOULD KNOW

The detailed information you need for advancement and for everyday work is contained in various publications. Some are subject to change or revision at regular intervals, while others are revised as the need arises. When using any publication that is subject to change or revision, be sure that you have the latest edition. When using any publication that is kept current by means of changes, be sure you have a copy in which all official changes have been made. Studying canceled or obsolete information will not help you to do your work or to advance; it is likely to be a waste of time, and may even be seriously misleading.

GOVERNMENT PUBLICATIONS

There are various government publications which you may find useful as sources of reference. A number of publications issued by the Naval Facilities Engineering Command (NAVFAC) which will be of interest to personnel in Occupational Field 13 (Construction) ratings are listed in the *Index of Naval Facilities Engineering Command Publications,* NAVFAC P-349 (updated semiannually). A publications program is one of the principal communications media used by NAVFAC to provide a ready reference of current technical and administrative data for use by its subordinate units.

NAVFAC publications are listed in alphabetical and numerical order in NAVFAC P-349; copies of NAVFAC P-349 may be obtained through proper channels from the Naval Supply Depot, 5801 Tabor Avenue, Philadelphia, Pennsylvania 19120.

Some of the publications that you will need to study or refer to as you prepare for advancement have already been discussed earlier in this chapter. Here are the titles and short descriptions of three more:

Tools and Their Uses. Although this training manual is not specifically required for advancement, you will find that it contains a good deal of useful information on the care and use of many common handtools and portable power tools.

Blueprint Reading and Sketching. Beginning with a general discussion of the uses and kinds of blueprints, the manual explains the common terms, symbols, and conventions used in connection with a variety of prints and drawings. Of particular interest to you is the chapter on machine drawings which includes engine drawings and diagrams.

The Metric System. This single-subject training manual and its associated OCC-ECC form a self-study package designed to train Navy personnel in converting English units of weight and measures to units in the metric or International System (SI). Note: For your immediate use, a listing of common equivalents and conversions is contained in Appendix I of this manual.

In addition, you may find it useful to consult the rate training manuals prepared for other construction ratings. Reference to these manuals will add to your knowledge of the duties of other people in the construction ratings.

U.S. Army technical manuals (TM's) provide information concerning operation and maintenance of all equipment procured by the U.S. Army. Much of this equipment is used by the SEABEES. TM's pertinent to equipment of this type are provided for your use in the maintenance shop.

COMMERCIAL PUBLICATIONS

There is a wealth of information for the Construction Mechanic field contained in reports, pamphlets, handbooks, and texts published by trade associations, technical and professional societies, and commercial publishing houses. Operator's manuals, maintenance manuals, and service bulletins supplied by the equipment manufacturers are of particular value to the mechanic performing "hands on" duties related to equipment maintenance. These publications are available in the maintenance shop ready reference. Other publications which provide comprehensive information on automotive and construction equipment are: *Automotive Mechanics* by William H. Grouse and *Moving The Earth* by H.L. Nichols Jr. Additional literature is available to you in the station library, the Public Works Department, and the Battalion library.

TRAINING FILMS

Training films available to naval personnel are a valuable source of supplementary information on many technical subjects. Training films are listed in the *United States Navy Film Catalog*, NAVAIR 10-1-777, published in 1971. Copies may be ordered in accordance with the *Navy Stock List of Forms and Publications*, NAVSUP 2002. Monthly supplements to the Film Catalog are distributed to catalog holders.

When selecting a film, note its date of issue listed in the Film Catalog. As you know, procedures sometimes change rapidly. Thus some films become obsolete rapidly. If a film is obsolete only in part, it may sometimes be shown effectively if before or during its showing you carefully point out to trainees the procedures that have changed.

18

CHAPTER 2

PRINCIPLES OF INTERNAL COMBUSTION ENGINES

As a Construction Mechanic, you will be concerned with repairing and replacing worn or broken parts, making various adjustments to vehicles and equipment, and seeing that vehicles and equipment are properly serviced and regularly inspected. To perform these duties intelligently, it is important that you fully understand the principles of internal combustion engine operation and the function of the various components that make up the internal combustion engine. This understanding will make your job of diagnosing trouble and making corrections much easier. You will find that you can save time, effort, and money by having a thorough knowledge of the theory and functions of the engine and its many components.

This chapter discusses basic principles of engine operation and briefly explains some of the terms used in connection therewith. You will hear many of these terms used around the shop and will see them in maintenance and repair manuals.

COMBUSTION ENGINE

Combustion is the act or process of burning. An internal or external combustion engine is defined simply as "a machine that converts this heat energy to mechanical energy." To fulfill this purpose, the engine may take one of several forms.

In the internal combustion engine, combustion takes place inside the cylinder and is directly responsible for forcing the piston to move down.

In external combustion engines, such as steam engines, combustion takes place outside the engine. Figure 2-1 shows, in simplified form, an external and an internal combustion engine.

The external combustion engine requires a boiler to which heat is applied. This combustion causes water to boil to produce steam. The steam passes into the engine cylinder under pressure and forces the piston to move downward.

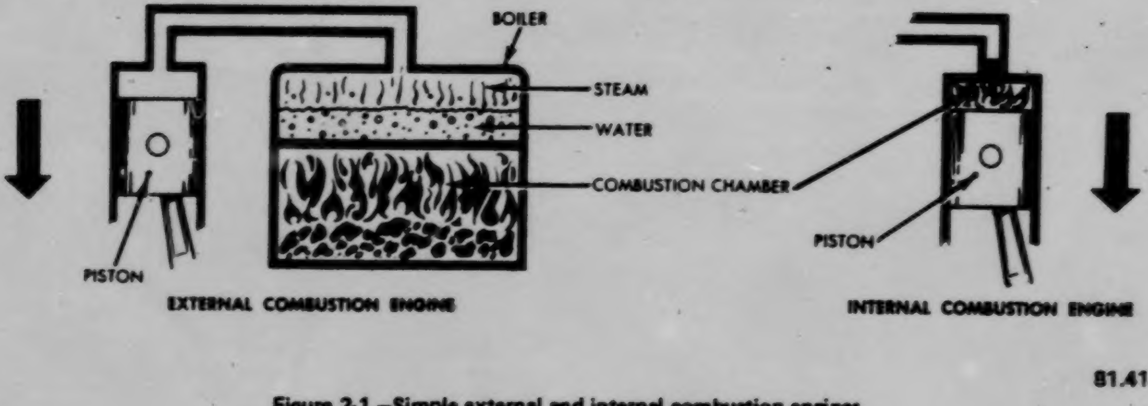


Figure 2-1.—Simple external and internal combustion engines.

The transformation of HEAT ENERGY to MECHANICAL ENERGY by the engine is based on a fundamental law of physics which states that gas will expand upon application of heat. The law also states that when a gas is compressed the temperature of the gas will increase. If the gas is confined with no outlet for expansion, then the pressure of the gas will be increased when heat is applied. In the internal combustion engine, the burning of a fuel within a closed cylinder results in an expansion of gases. This expansion creates pressure on top of a piston, causing it to move downward. In an internal combustion engine, the piston moves up and down within a cylinder.

This up-and-down motion is known as RECIPROCATING MOTION. This reciprocating motion (straight line motion) must be changed to ROTARY MOTION (turning motion) in order to turn the wheels of a vehicle. A crankshaft and a connecting rod change this reciprocating motion to rotary motion.

All internal combustion engines, whether gasoline or diesel, are basically the same. We can best demonstrate this by saying they all rely on three things–FUEL, AIR, AND IGNITION.

FUEL contains potenial energy for operating the engine. AIR contains the oxygen necessary for combustion; and IGNITION starts combustion. All are fundamental, and the engine will not operate without any one of them. Any discussion of engines must be based on these three factors and the steps and mechanisms involved in delivering them to the combustion chamber at the proper time.

DEVELOPMENT OF POWER

The power of an internal combustion engine comes from burning a mixture of fuel and air in a small, enclosed space. When this mixture burns it expands greatly, and the push or pressure created is used to move the piston, thereby rotating the crankshaft. This movement is eventually sent back to the wheels to drive the vehicle.

Since similar action occurs in all cylinders of an engine, let's use one cylinder to describe the steps in the development of power. The 1-cylinder engine consists of four basic parts as shown in figure 2-2.

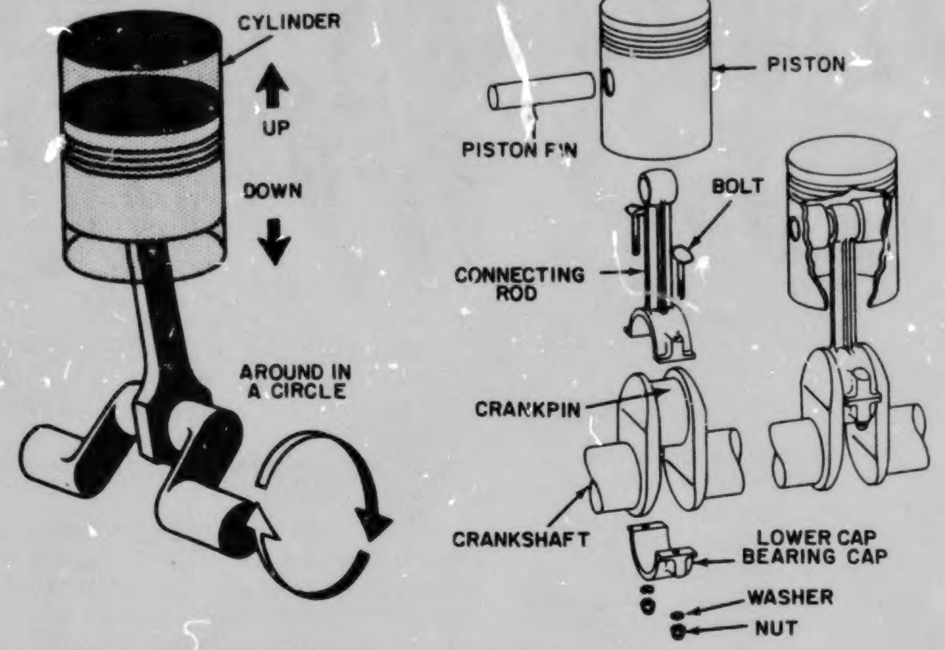
First we must have a CYLINDER which is closed at one end; this cylinder is similar to a tall metal can which is stationary within the engine block.

Inside this cylinder is the PISTON, a movable metal plug, which fits snugly into the cylinder, but can still slide up and down easily. This movement of the piston is caused by the burning of fuel in the cylinder resulting in the production of reciprocating motion.

You have already learned that the up-and-down movement of the piston is called reciprocating motion. This motion must be changed to rotary motion so the wheel or tracks of vehicles can be made to rotate. This change is accomplished by a throw on the CRANKSHAFT and a CONNECTING ROD which connects the piston and the crankshaft throw.

The throw is an offset section of the crankshaft, which scribes a circle as the shaft rotates. The top end of the connecting rod is connected to the piston and must therefore go up and down. The lower end of the connecting rod is attached to the crankshaft. The lower end of the connecting rod also moves up and down but, because it is attached to the crankshaft, it must also move in a circle.

When the piston of the engine slides downward because of the pressure of the expanding gases in the cylinder, the upper end of the connecting rod moves downward with the piston, in a straight line. The lower end of the connecting rod moves down and in a circular motion at the same time. This moves the throw and, in turn, the throw rotates the crankshaft; this rotation is the desired result. So remember, the crankshaft and connecting rod combination is a mechanism for the purpose of changing straight line, or reciprocating motion to circular, or rotary motion.


CYLINDER
UP
DOWN
AROUND IN A CIRCLE
PISTON
PISTON PIN
BOLT
CONNECTING ROD
CRANKPIN
CRANKSHAFT
LOWER CAP BEARING CAP
WASHER
NUT

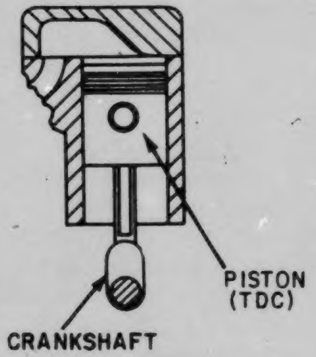
65.95(81C)

Figure 2-2.—Cylinder, piston, connecting rod, and crankshaft for 1-cylinder engine.

BASIC ENGINE STROKES

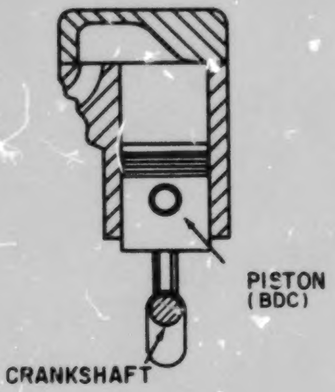
Each movement of the piston from top to bottom or from bottom to top is called a stroke. The piston takes two strokes (an upstroke and a downstroke) as the crankshaft makes one complete revolution. When the piston is at the top of a stroke (fig. 2-3), it is said to be at top dead center (TDC). When the piston is at the bottom of a stroke (fig. 2-4), it is said to be at bottom dead center (BDC). These positions are called rock positions and will be discussed further in this chapter under "Timing."

The basic engine you have studied so far has no provisions for getting the fuel-air mixture into the cylinder or burned gases out of the cylinder. There are two openings in the enclosed end of a cylinder. One of the openings, or ports, permits an intake of air or an intake of a mixture of fuel and air into the combustion area of the cylinder. The other opening or port permits the burned gases to escape from the cylinder. The two ports have valves in them. These valves, activated by the camshaft, close off either one or the other of the ports, or both of them, during various stages of engine operation. The camshaft has a number of lobes along its length that open the valves and


PISTON (TDC)
CRANKSHAFT

81.42.1

Figure 2-3.—Piston top dead center (TDC).



81.42.5
Figure 2-4.–Piston bottom dead center (BDC).

hold them open for the correct length of time during the piston stroke. The camshaft is driven by the crankshaft through timing gears, or by means of a timing chain. On a 4-stroke cycle engine the camshaft turns at one-half the crankshaft speed. This permits each valve to open and close once for every two revolutions of the crankshaft. One of the valves, called the intake valve, opens to admit an intake of air or a mixture of fuel and air into the cylinder. The other valve, called the exhaust valve, opens to allow the escape of burned gases after the fuel-and-air mixture has burned. In the next chapter you will learn more about how these valves and their mechanisms operate.

The following paragraphs give a simplified explanation of the action that takes place within the engine cylinder. For the purpose of explanation, we will illustrate the action of a 4-stroke cycle gasoline engine. This type engine is referred to as a 4-stroke cycle because it requires four complete strokes of the piston to complete one engine cycle. Later in the chapter, a 2-stroke cycle engine will be discussed. The action of a 4-stroke cycle engine may be divided into four parts: the intake stroke, the compression stroke, the power stroke, and the exhaust stroke.

INTAKE STROKE

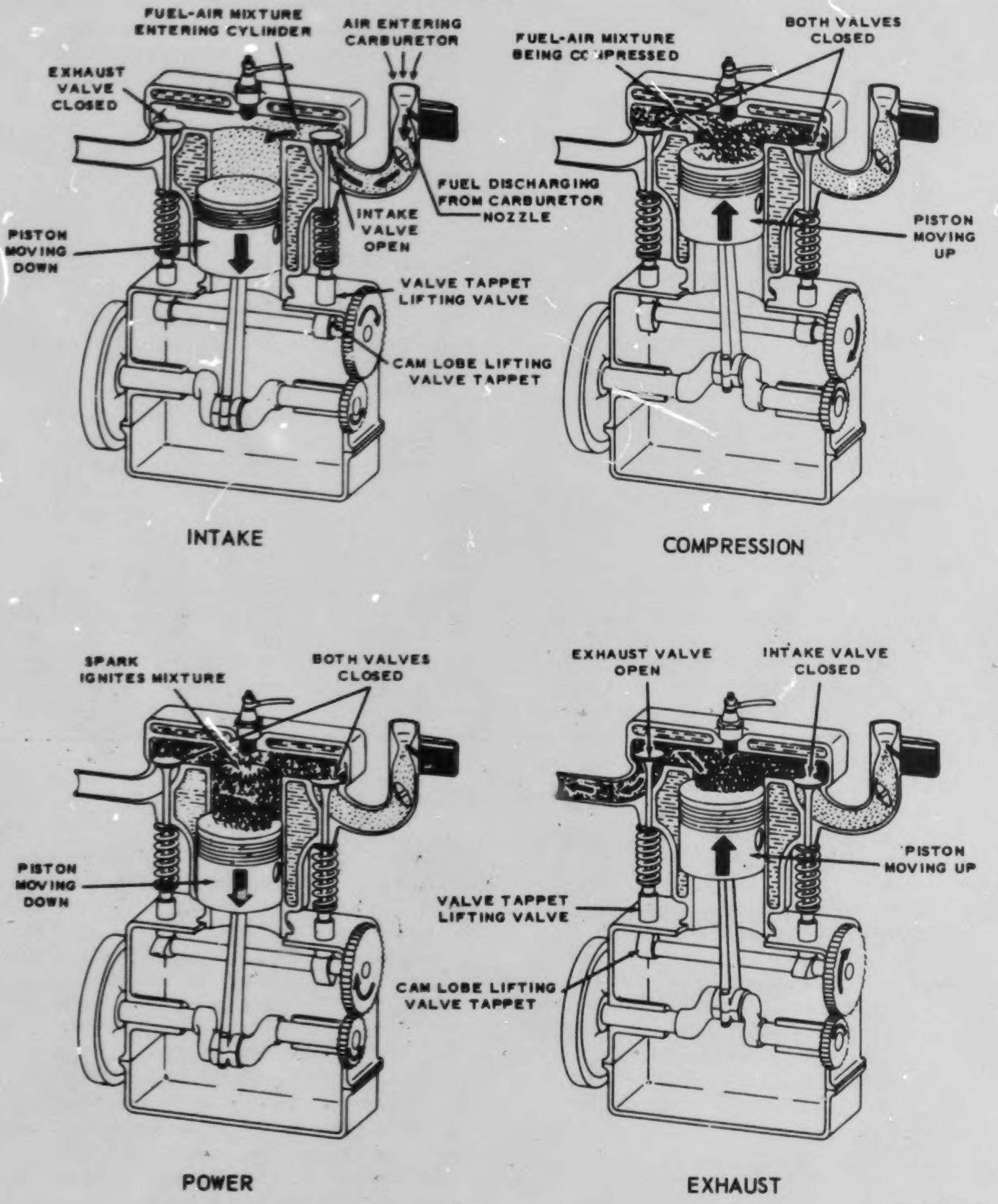
The first stroke in the sequence is called the INTAKE stroke (fig. 2-5). During this stroke, the piston is moving downward and the intake valve is open. This downward movement of the piston produces a partial vacuum in the cylinder, and air-fuel mixture rushes into the cylinder past the open intake valve. This is somewhat the same effect as when you drink through a straw. A partial vacuum is produced in the mouth and the liquid moves up through the straw to fill the vacuum.

COMPRESSION STROKE

When the piston reaches bottom dead center at the end of the intake stroke and is therefore at the bottom of the cylinder, the intake valve closes. This seals the upper end of the cylinder. As the crankshaft continues to rotate, it pushes up, through the connecting rod, on the piston. The piston is therefore pushed upward and compresses the combustible mixture in the cylinder; this is called the COMPRESSION stroke (fig. 2-5). In gasoline engines, the mixture is compressed to about one-eighth of its original volume; which is called an 8 to 1 compression ratio. This compression of the air-fuel mixture increases the pressure within the cylinder. Compressing the mixture in this way makes it still more combustible; not only does the pressure in the cylinder increase, but the temperature of the mixture also increases.

POWER STROKE

As the piston reaches top dead center at the end of the compression stroke and therefore has moved to the top of the cylinder, the compressed fuel-air mixture is ignited. The ignition system causes an electric spark to occur suddenly in the cylinder, and the spark ignites the fuel-air mixture. In burning, the mixture gets very hot and tries to expand in all directions. The pressure rises to about 600 or 700 pounds per square inch. Since the piston is the only thing that can move, the force produced by the expanding gases forces the piston down. This force, or thrust, is carried through the connecting rod to the crankshaft throw on the crankshaft. The crankshaft is given a powerful push. This is called the POWER stroke (fig. 2-5). This turning effort, rapidly repeated in the


FUEL-AIR MIXTURE ENTERING CYLINDER
AIR ENTERING CARBURETOR
EXHAUST VALVE CLOSED
FUEL DISCHARGING FROM CARBURETOR NOZZLE
INTAKE VALVE OPEN
PISTON MOVING DOWN
VALVE TAPPET LIFTING VALVE
CAM LOBE LIFTING VALVE TAPPET
INTAKE
FUEL-AIR MIXTURE BEING COMPRESSED
BOTH VALVES CLOSED
PISTON MOVING UP
COMPRESSION
SPARK IGNITES MIXTURE
BOTH VALVES CLOSED
PISTON MOVING DOWN
POWER
EXHAUST VALVE OPEN
INTAKE VALVE CLOSED
PISTON MOVING UP
VALVE TAPPET LIFTING VALVE
CAM LOBE LIFTING VALVE TAPPET
EXHAUST

54.19(65B)

Figure 2-5.—Four-stroke cycle in a gasoline engine.

23

engine and carried through gears and shafts, will turn the wheels of a vehicle and cause it to move.

EXHAUST STROKE

After the fuel-air mixture has burned, it must be cleared from the cylinder. This is done by opening the exhaust valve just as the power stroke is finished and the piston starts back up on the EXHAUST stroke (fig. 2-5). The piston forces the burned gases out of the cylinder past the open exhaust valve.

ENGINE CYCLES

The four strokes (intake, compression, power, and exhaust) are continously repeated as the engine runs. Now, with the basic knowledge you have of the parts and the four strokes of the engine, let us see what happens during the actual running of the engine. To produce sustained power, an engine must accomplish the same series of events–intake, compression, power, and exhaust–over and over again.

This series of events is called a cycle. Remember that in a 4-stroke cycle engine it takes four complete strokes of the piston to complete one engine cycle.

Most engines that you will deal with are of the 4-stroke cycle design.

2-STROKE CYCLE ENGINE

In the 2-stroke cycle engine, the same four events (intake, compression, power, and exhaust) take place in only two strokes of the piston and one complete revolution of the crankshaft.

A 2-stroke cycle diesel engine is shown in figure 2-6. Each time the piston moves down, it is on the power stroke. Since this engine does the same thing in half as many strokes as the 4-stroke cycle engine, let's take a closer look at its construction. Instead of intake valves, it has holes, called inlet ports, surrounding the cylinder walls. It also has a blower to force the air into the cylinder when the inlet ports are uncovered by the piston on its downward stroke. Since this engine is a diesel, it requires no spark plugs–only a means of introducing fuel into the cylinder where the fuel burns due to the high temperature of the compressed air.

Here is how one cycle occurs with only two strokes of the piston. The sequence of events is intake, compression, power, and exhaust. Intake begins when the inlet ports are uncovered as the piston moves down in the cylinder. It continues until the piston moves up, covering the ports and blocking the airflow into the cylinder. Very shortly after the inlet ports are covered, the exhaust valve closes and the compression stroke begins.

During the compression stroke, the air is compressed to ignite the fuel which is injected near the end of the upward movement of the piston.

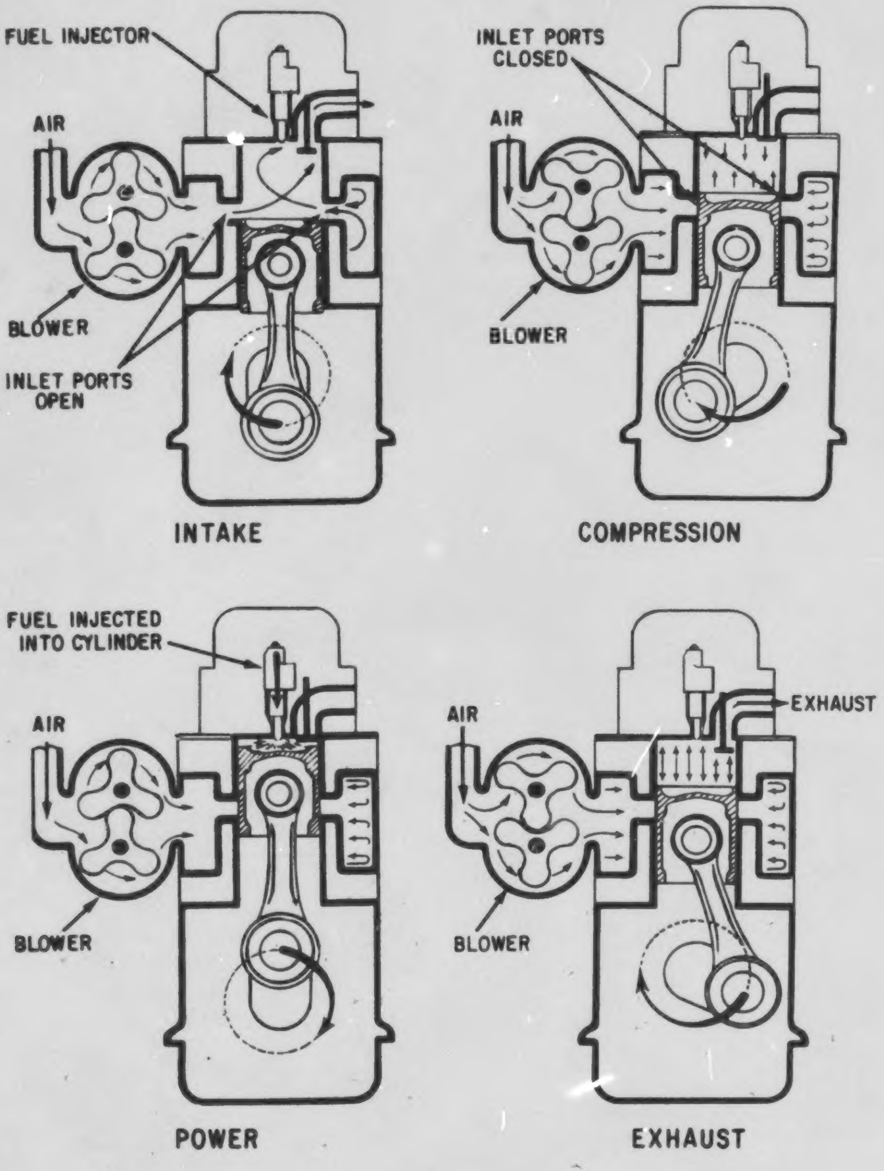
The pressure from combustion forces the piston down on the power stroke.

As the piston nears the intake ports, the exhaust valve opens, starting the exhaust event, and allowing the burned gases to start escaping. The continued downward motion of the piston uncovers the inlet port, then air (under pressure) is forced into the cylinder and aids the exhaust event by pushing the burned gases out of the cylinder. This cleaning action is referred to as exhaust gas scavenging. Details on the relationship of piston covering and uncovering inlet ports and exhaust valves opening and closing are given later.

4-STROKE CYCLE VS 2-STROKE CYCLE

As indicated earlier, a power stroke is produced every crankshaft revolution within the 2-stroke cycle engine, whereas the 4-stroke cycle engine requires two crankshaft revolutions for one power stroke.

It might appear, then, that the 2-stroke cycle could produce twice as much power as the 4-stroke cycle of the same size, operating at the same speed. However, this power increase is limited to approximately 70 to 80% because


FUEL INJECTOR
AIR
BLOWER
INLET PORTS OPEN
INTAKE
INLET PORTS CLOSED
AIR
BLOWER
COMPRESSION
FUEL INJECTED INTO CYLINDER
AIR
BLOWER
POWER
AIR
EXHAUST
BLOWER
EXHAUST

54.20

Figure 2-6.—Two-stroke cycle in a diesel engine.

some of the power is employed to drive a blower that forces the air charge into the cylinder under pressure. Also, the burned gases are not completely cleared from the cylinder, reducing combustion efficiency. Additionally, because of the much shorter period the intake port is open (as compared to the period the intake valve in a 4-stroke is open), a relatively smaller amount of air is admitted. Hence, with less air, less power per power stroke is produced in a 2-stroke cycle engine of like size operating at the same speed with conditions being the same.

MULTIPLE-CYLINDER ENGINES

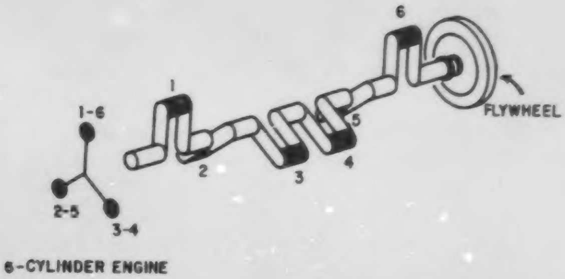
The discussion so far in this chapter has been on a single-cylinder engine. A single cylinder provides only one power impulse every two crankshaft revolutions in a 4-stroke cycle engine and is delivering power only one-fourth of the time. To provide for a more continuous flow of power, modern engines use four, six, eight or more cylinders. The same series of cycles previously discussed take place in each cylinder.

In a 4-stroke cycle, 6-cylinder engine, for example, the throws on the crankshaft are set 120 degrees apart, the throws for cylinders 1 and 6, 2 and 5, and 3 and 4 being in line with each other (fig. 2-7). The cylinders fire or deliver the power strokes in the following order: 1-5-3-6-2-4. Thus the power strokes follow each other so closely that there is a fairly continuous and even delivery of power to the crankshaft.

Even so, additional leveling off of the power impluses is desirable, so that the engine will run more smoothly. A flywheel (fig. 2-7) is used to achieve this result.

To understand how a flywheel functions, let us consider a single cylinder engine. It is delivering power only one-fourth of the time during the power stroke. During the other three strokes it is absorbing power to push out the exhaust gas, to pull in a fresh charge, and to compress the charge. The flywheel makes the engine run without varying much in speed during each revolution. It is a heavy steel wheel, attached to the end of the crankshaft. When it is rotating, considerable effort is required to slow it down or stop it. Thus, although the wheel does slow down somewhat as it delivers power to the engine during the exhaust, intake, and compression strokes, the wheel speed increases during the engine power stroke. In effect, the flywheel absorbs some of the engine power during the power stroke, and then gives it back to the engine during the other three engine strokes.

In the multicylinder engine the flywheel functions in a similar manner, absorbing power when the engine tends to speed up during the power strokes and giving up power to the engine when the engine tends to slow down during intervals when little power is being delivered by the engine.



75.81(81D)

Figure 2-7.—Crankshaft for a 6-cylinder engine.

In addition to the engine itself, which is the power producer, there must be accessory systems to provide the engine with other requirements necessary to operate it. These systems are (1) the fuel system, (2) the lubrication or oiling system, (3) the electric system, (4) the cooling system, and (5) an exhaust system. Each of these systems will be discussed in later chapters in this manual.

CLASSIFICATION OF ENGINES

Engines for automotive and construction equipment may be classified in a number of ways: type of fuel used; type of cooling employed; or valve and cylinder arrangement. They all operate on the internal combustion principle, and the application of basic principles of construction to particular needs or systems of manufacture has caused certain designs to be recognized as conventional.

The most common method of classification is by the type of fuel used; that is, whether the engine burns gasoline or diesel fuel.

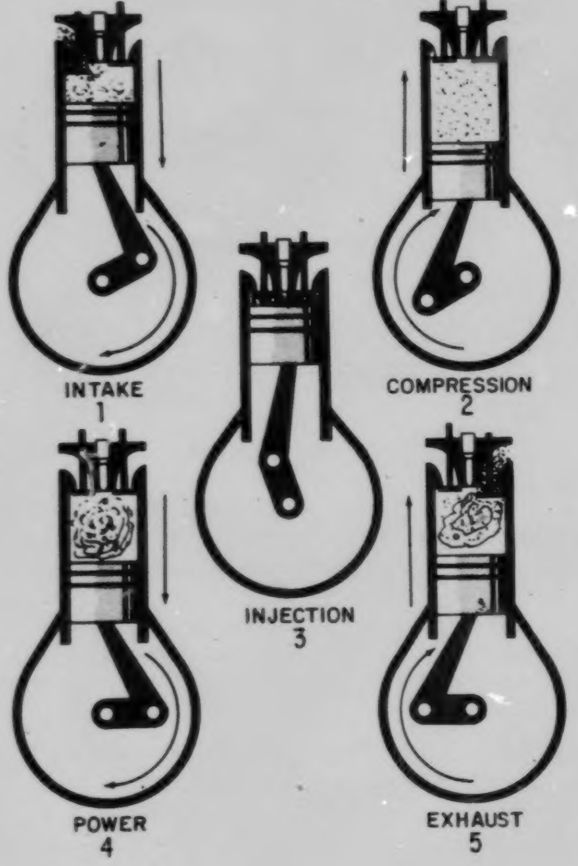
GASOLINE ENGINES VS DIESEL ENGINES

Mechanically and in overall appearance, gasoline and diesel engines resemble one another. However, in the diesel engine, many parts are somewhat heavier and stronger, so that they can withstand the higher temperatures and pressures the engine generates. The engines differ also in the fuel used, in the method of introducing it into the cylinders, and in how the air-fuel mixture is ignited. In the gasoline engine, air and fuel first are mixed together in the carburetor. After this mixture is compressed in the cylinders, it is ignited by an electrical spark from the spark plugs.

The diesel engine has no carburetor. Air alone enters its cylinders, where it is compressed and reaches high temperature due to compression. The heat of compression ignites the fuel injected into the cylinder and causes the air-fuel mixture to burn. The diesel engine needs no spark plugs; the very contact of the diesel fuel with the hot air in the cylinders causes ignition. In the gasoline engine the heat from compression is not enough to ignite the air-fuel mixture; therefore, spark plugs are necessary.

OPERATING CYCLES

In the preceding paragraphs you learned about the operating cycles of the internal combustion engine. The following summarizes the main points of this subject. Figure 2-5 illustrates the strokes of the 4-stroke cycle gasoline engine, and figure 2-8 illustrates the strokes of the 4-stroke cycle diesel engine. In each cylinder of either engine, four strokes of the piston require two revolutions of the crankshaft and one revolution of the camshaft to complete the cycle of the four events of INTAKE, COMPRESSION, POWER, AND EXHAUST. In the 2-stroke cycle engine (fig. 2-6), two piston strokes are required to accomplish these four events. This engine produces less energy per power stroke, but since the power stroke occurs twice as often, it is as efficient, or more so, than a 4-stroke cycle engine of the same size and operating speed.



54.19(81C)

Figure 2-8.—Four-stroke cycle diesel engine.

ARRANGEMENT OF CYLINDERS

Engines are classified also according to the arrangement of the cylinders: INLINE, with all cylinders cast in a straight line above the crankshaft, and V-TYPE with two banks of cylinders mounted in a V shape above the crankshaft. While these are the two most common arrangements, you might work occasionally with a HORIZONTALLY OPPOSED engine, whose cylinders are mounted in two side rows, each opposite a central crankshaft. Buses often are equipped with such engines.

The cylinders are numbered. The cylinder nearest the front of an inline engine is number 1. The others are numbered 2,3,4, etc., from front to rear. In V-type engines the numbering sequence varies with the manufacturer. You should consult his manual for the correct order.

The FIRING ORDER (which is different from the NUMBERING ORDER) of the cylinders of most of the engines with which you will be working is stamped on the cylinder block or on the manufacturer's nameplate. If you are unable to find the firing order, and no operation or instruction manual is at hand to guide you, turn the engine over by the crankshaft and watch the order in which the intake valves open.

VALVE ARRANGEMENT

The majority of internal combustion engines also are classified according to the position and arrangement of the intake and exhaust valves–that is, whether the valves are in the cylinder block or in the cylinder head. Various arrangements have been used, but the most common are L-head, I-head, and F-head (fig. 2-9). The letter designation is used because the shape of the combustion chamber resembles the form of the letter identifying it.

L-Head

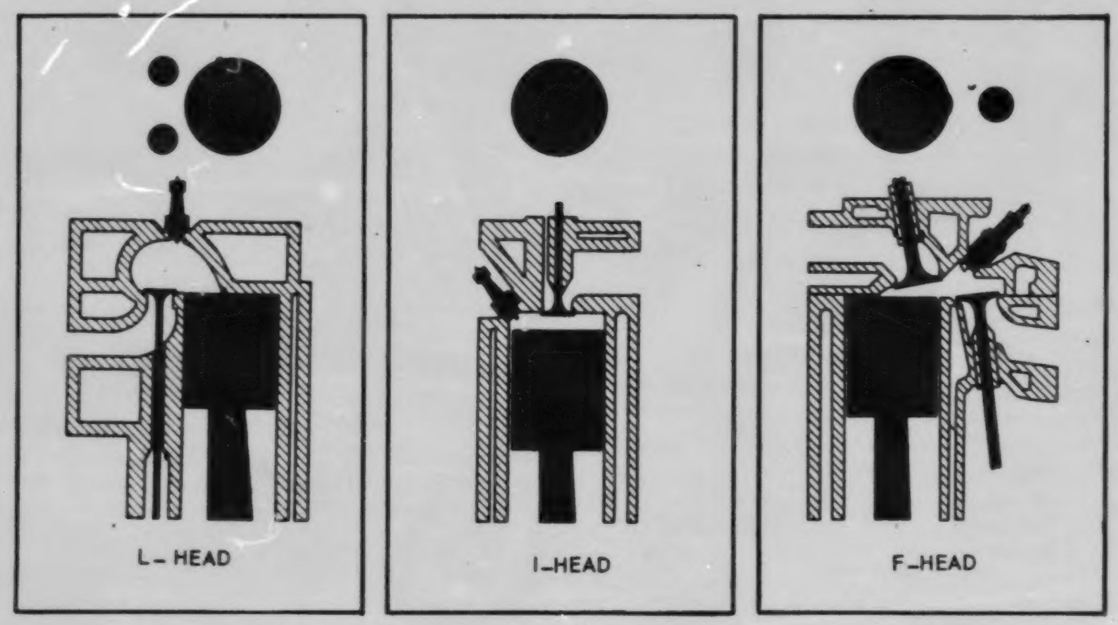
In the L-head engines both valves are placed in the block on the same side of the cylinder. The valve-operating mechanism is located directly below the valves, and one camshaft actuates both the intake and exhaust valves.

I-Head

Engines using the I-head construction are commonly called VALVE-IN-HEAD or OVERHEAD VALVE engines, because the valves are mounted in a cylinder head above the cylinder. This arrangement requires a tappet, a push rod, and a rocker arm above the cylinder to reverse the direction of valve movement, but only one camshaft is required for both valves. Some overhead valve engines make use of an overhead camshaft. This arrangement eliminates the long linkage between the camshaft and valve.

F-Head

In the F-head engine, the intake valves normally are located in the head, while the



81.46

Figure 2-9.–L-, I-, and F-valve arrangement.

exhaust valves are located in the engine block. This arrangement combines, in effect, the L-head and the I-head valve arrangements. The valves in the head are actuated from the camshaft through tappets, push rods, and rocker arms (I-head arrangement), while the valves in the block are actuated directly from the camshaft by tappets (L-head arrangement).

Occasionally you may work on older engines with T-HEAD valves where both valves are set in the block, but on opposite sides of the cylinders. You will also find some engines, both 2-stroke and 4-stroke cycle, that have two to four exhaust valves per cylinder. On any other unusual valve arrangement that you may encounter, refer to the manufacturer's specifications or consult your Chief.

ENGINE MEASUREMENTS AND PERFORMANCE

As a mechanic you will have to know the various ways in which engines and engine performance are measured. An engine may be measured in terms of cylinder diameter, piston stroke, and number of cylinders. It may be measured, performance wise, in terms of the torque and horsepower it develops, and in efficiency. These various terms, their meanings, and their application will be discussed here. But, before you get into the discussion, there are a few engineering terms with which you need to become familiar.

DEFINITIONS

WORK, in the mechanical sense of the term, is done when a resistance is overcome by a force acting through a measured distance. When a weight is lifted from the ground, work is done on the weight. It is moved upward against the force of gravity. When a bulldozer pushes over a tree, work is done as it forces it to the ground. If a 1-lb weight is lifted 1 ft, 1 FOOT-POUND of work is done.

ENERGY is the ability to do work. When work is done on a body, energy is stored in that body. The higher a weight is lifted from the ground, the more energy is stored in the weight. Then, when it falls, it will strike the ground hard; that is, it will do more work on the ground.

POWER is the rate at which work is done. It takes more power to work rapidly than to work slowly. Engines are rated in terms of the amount of work they can do per minute. An engine which can do more work per minute than another is said to be more powerful.

The work capacity of an engine is measured in horsepower. A HORSEPOWER (hp) is the power of a horse, or a measure of the rate at which a horse can do work. It has been found that an average horse can lift a weight of 200 lb a distance of 165 ft in 1 minute. The amount of work involved here is 33,000 foot-pounds (165 times 200). If 100 lb were lifted 330 ft, or if 330 lb were lifted 100 ft, the amount of work would be the same, 33,000 foot-pounds. When this amount of work is done in 1 minute, then 1 horsepower is required. If it takes 2 minutes to do this amount of work, then 16,500 foot-pounds per minute, or 1/2 hp, would be required. The formula for horsepower is

$$\text{hp} = \frac{\text{ft-lb. per min}}{33{,}000} = \frac{L \times W}{33{,}000 \times t}$$

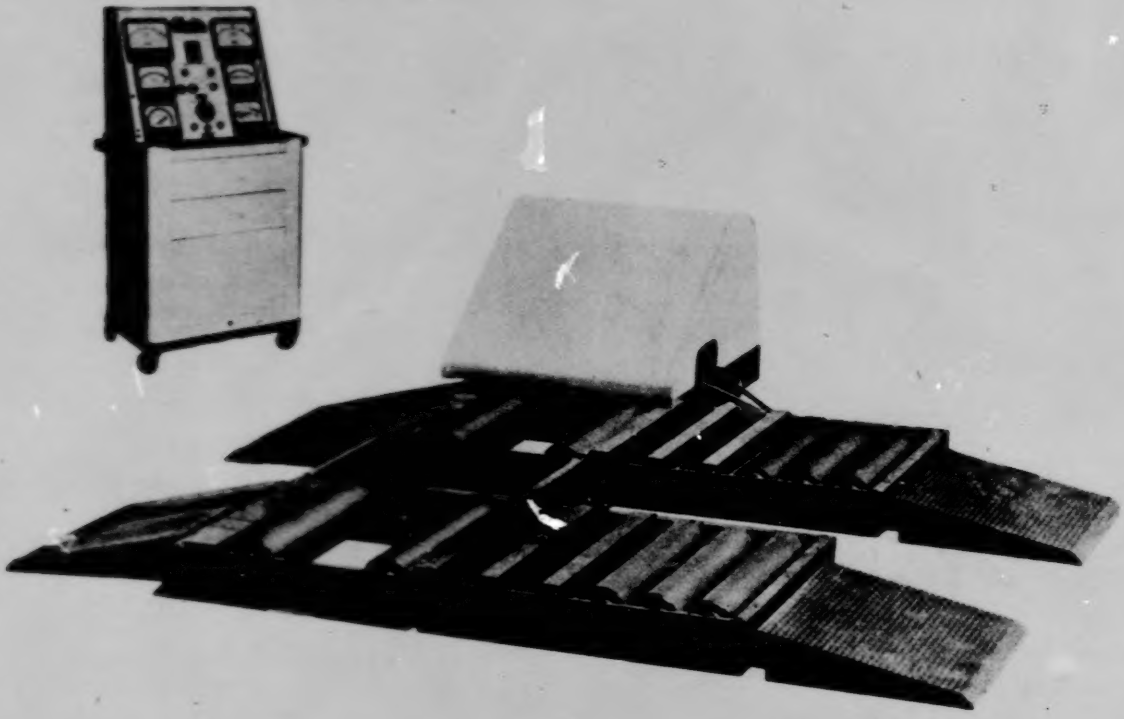
L = length, in feet, through which W is moved

W = force, in pounds, that is exerted through distance L

t = time, in minutes, required to move W through L

There are a number of devices that may be used to measure the hp of an engine. The most common device used for this purpose is the dynamometer.

An ENGINE DYNAMOMETER may be used to test an engine that has been removed from the vehicle it drives. If the engine does not develop the manufacturer's recommended horsepower and torque at specific rpm's, you



2.16X

Figure 2-10.—Chassis dynamometer.

know there is need for further adjustments and/or repairs on the engine.

The CHASSIS DYNAMOMETER is used for automotive service, since it can give a very quick report on engine conditions by measuring output at various speeds and loads. This type of machine is very useful in shop testing and adjusting automatic transmissions.

On the chassis dynamometer, figure 2-10 the driving wheels of the vehicle are placed on rollers. The engine drives the wheels and the wheels drive the rollers. By loading the rollers varying amounts and by running the engine at different rpm's, nearly all normal driving conditions can be simulated. The tests and checks can be made without the interference of body noises, such as you would have when checking the vehicle on the road.

TORQUE is twisting, or turning, effort. When the lid on a jar is loosened, a twisting force, or torque, is applied to it. You apply torque to a wrench when you tighten or loosen a nut. Torque is measured in pound-feet (not to be confused with work, which is measured in foot-pounds). For instance, suppose a wrench is used to tighten a nut on a stud. If the handle of the wrench were 1-ft long and a 10-lb force were put on its end, 10 pound-feet of torque would be applied to the nut. An illustration of a torque wrench in use is shown in figure 2-11.

Do not confuse torque with work or with power. Both work and power indicate motion, but torque does not. It is merely a turning effort the engine applies to the wheels through gears and shafts.

FRICTION is the resistance to motion between two objects in contact with each other.

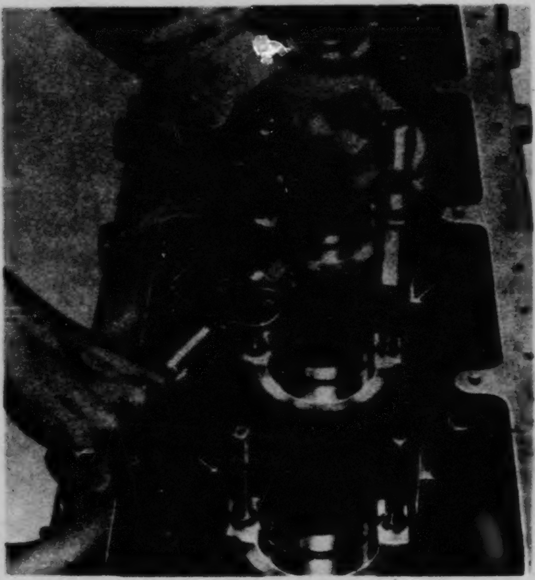


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Figure 2-11.—Torque wrench in use, tightening main bearing stud of an engine.

The reason a sled will not slide on bare earth is because of friction. It slides on snow because snow offers little resistance, while the bare earth offers much resistance.

Friction is both desirable and undesirable in an automobile or any other vehicle. Friction in the engine is undesirable because it decreases the power output; in other words, it uses up some of the energy of the engine. This is overcome by using oil so the moving components in the engine will slide or roll over each other smoothly. Friction is desirable in clutches and brakes since friction is exactly what is needed for them to perform their function properly.

One other term you will often encounter is INERTIA. Inertia is a characteristic of all material objects. It causes them to resist any change of speed or direction of travel. A motionless object tends to remain at rest and a moving object tends to keep moving at the same speed and in the same direction. A good example of inertia is the tendency of your automobile to keep moving after your foot is removed from the accelerator. You apply the brake to overcome the inertia of the automobile, or its tendency to keep moving.

The term EFFICIENCY means the relationship between the actual and theroretical power output.

VOLUMETRIC EFFICIENCY is the ratio between the amount of fuel-air mixture that actually enters the cylinder and the amount that could enter under ideal conditions. The greater the volumetric efficiency, the greater the amount of fuel-air mixture entering the cylinder; and the greater the amount of fuel-air mixture, the more power produced from the engine cylinder.

Volumetric efficiency can be improved by using a blower, or air-compressing device. On gasoline engines this device is called a supercharger. It raises the air pressure above atmospheric pressure so that the air is pushed into the cylinder.

MECHANICAL EFFICIENCY is the relationship between brake horsepower (bhp) and indicated horsepower (ihp). Brake horsepower is the actual power put out by the engine, while ihp is the power developed inside the cylinder. From mechanical efficiency you can tell what percentage of the power developed in the cylinder is actually being delivered by the engine. The remaining percent of power which is not delivered is consumed by friction, sometimes computed as friction horsepower (fhp).

The term THERMAL means "of or pertaining to heat." THERMAL EFFICIENCY of the engine is the relationship between the power output and the energy in the fuel burned to produce this output. Thermal efficiency has a direct relationship to heat losses in the engine. Because there is a great deal of heat lost during engine operation, thermal efficiency usually remains quite low at about 20 to 25 percent.

LINEAR MEASUREMENTS

The size of an engine cylinder is usually indicated in terms of bore and stroke. (See fig. 2-12.) BORE is the inside diameter of the

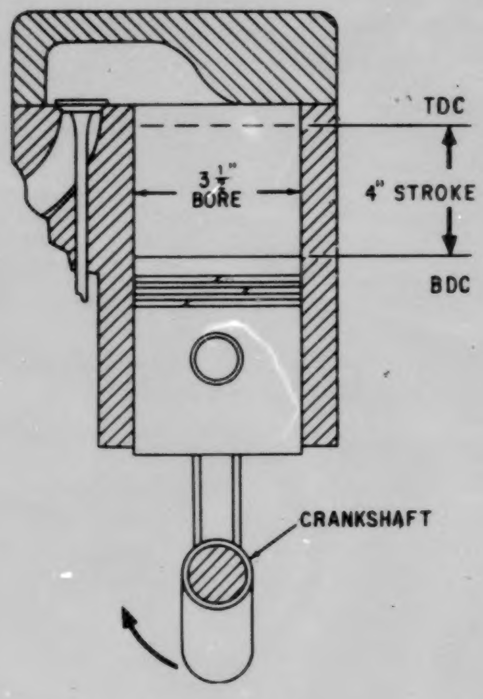

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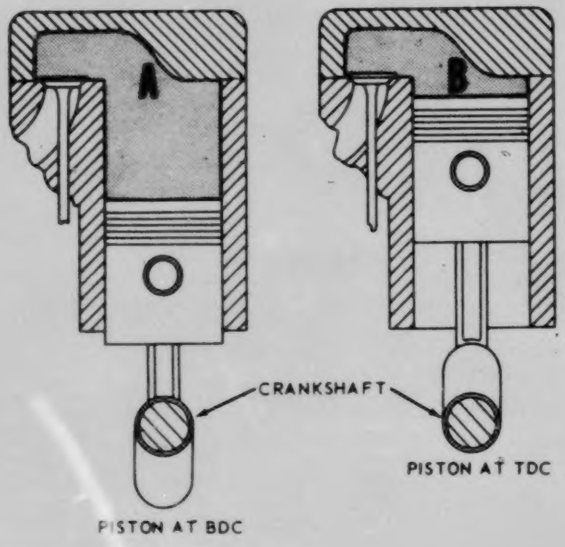
Figure 2-12.—Bore and stroke of an engine cylinder.



81.43

Figure 2-13.—Compression ratio is ratio between A and B.

cylinder. STROKE is the distance between top dead center and bottom dead center. The bore is always metioned first. For example, a 3 1/2 x 4 cylinder means that the cylinder bore, or diameter, is 3 1/2 inches and the length of the stroke is 4 inches. These measurements are used to figure piston displacement.

PISTON DISPLACEMENT is the volume of space that the piston displaces as it moves from one end of the stroke to the other. Thus the piston displacement in a 3 1/2-inch by 4-inch cylinder would be the area of a 3 1/2-inch circle multiplied by 4, the length of the stroke. The area of a circle is πR^2 where R is the radius (that is, one-half the diameter) of the circle. Letting S be the length of the stroke, the formula for the volume (V) is

$$V = \pi R^2 \times S$$

If this formula is applied to figure 2-12, the piston displacement is computed as follows:

$R = 1/2$ the diameter $= 1/2 \times 3.5 = 1.75$ in.
$\pi = 3.14$

then $V = \pi (1.75)^2 \times 4$

$V = 3.14 \times 3.06 \times 4$

$V = 38.43$ cu in.

The total displacement of an engine is found by multiplying the volume of one cylinder by the total number of cylinders.

ENGINE PERFORMANCE

The COMPRESSION RATIO of an engine is a measurement of how much the air-fuel charge is compressed in the engine cylinder. It is calculated by dividing the volume of one cylinder with the piston at BDC by the volume with the piston TDC (fig. 2-13). One should note that the volume, space B in figure 2-13 is called the clearance volume.

For example, suppose that an engine cylinder has a volume of 63 cu in. with the piston at BDC, and a volume of 10 cu in. with the piston at TDC. The compression ratio of this cylinder would be 6.3 to 1, determined by dividing 63 cubic inches by 10 cubic inches. That is, the air-fuel mixture is compressed from 63 to 10 cu. in. or to 1/6.3 of its original volume.

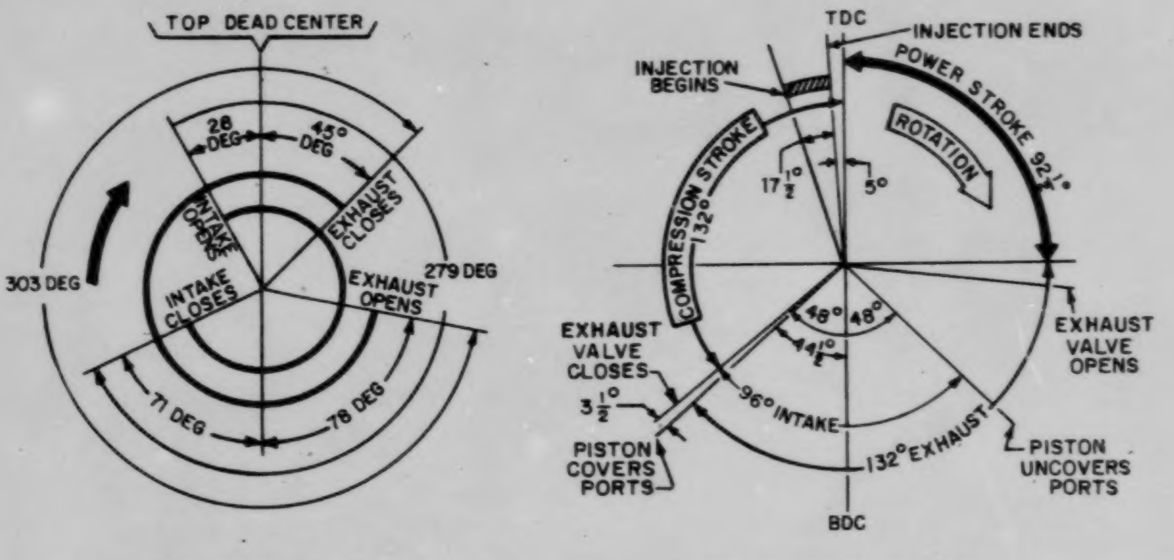
Two major advantages of increasing compression ratio are that power and economy of the engine improve without any added weight or size. The improvements come about because with a higher compression ratio the air-fuel mixture is squeezed more. This means a higher initial pressure at the start of the power stroke. As a result, there is more force on the piston for a greater part of the power stroke. Therefore, more power is obtained from each power stroke.

Increasing the compression ratio, however, brings up some problems. Fuel will stand only a certain amount of squeezing without knocking. Knocking is the sudden burning of the fuel-air mixture which causes a quick increase in pressure and a resulting rapping or knocking noise. The fuel chemists have overcome this knocking by creating antiknock fuels. (Antiknock fuels are described in a later chapter of this manual.)

Oxygen must be present if combustion is to occur in the cylinder, and since air is the source of supply of oxygen used in engines, the problem arises of getting the proper amount of air to support combustion. This factor is commonly known as the AIR-FUEL RATIO. A gasoline engine normally operates at intermediate speeds on a 15 to 1 ratio; that is, 15 pounds of air to 1 pound of gasoline.

TIMING

In a gasoline engine, the valves must open and close at the proper times with regard to piston position and stroke. In addition, the ignition system must produce the sparks at the proper time so that the power strokes can start. Both valve and ignition system action must be properly timed if good engine performance is to be obtained.


TOP DEAD CENTER
28 DEG
45° DEG
INTAKE OPENS
EXHAUST CLOSES
INTAKE CLOSES
EXHAUST OPENS
303 DEG
279 DEG
71 DEG
78 DEG
TDC
INJECTION ENDS
INJECTION BEGINS
POWER STROKE 92½°
ROTATION
COMPRESSION STROKE 132°
17½°
5°
48°
48°
44½°
EXHAUST VALVE CLOSES
3½°
96° INTAKE
132° EXHAUST
EXHAUST VALVE OPENS
PISTON COVERS PORTS
PISTON UNCOVERS PORTS
BDC

4-STROKE VALVE TIMING DIAGRAM

2-STROKE VALVE TIMING DIAGRAM

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Figure 2-14.—Typical valve timing diagrams.

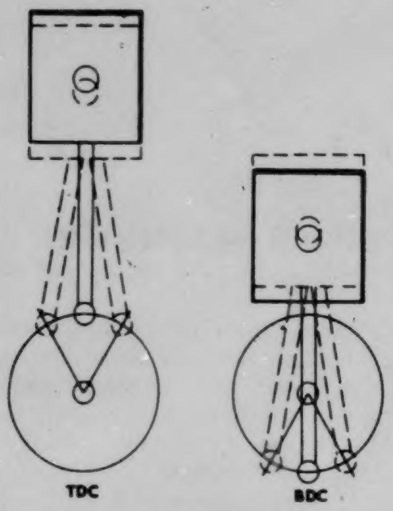

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Figure 2-15.–Rock position.

VALVE TIMING refers to the exact times in the engine cycle at which the valves trap the mixture and then allow the burned gases to escape. The valves must open and close so that they are constantly in step with the piston movement in the cylinder where they are located. The position of the valves is determined by the camshaft; the position of the piston is determined by the crankshaft. Correct valve timing is obtained by providing the proper relationship between the camshaft and the crankshaft. In actual operation the time at which the valves operate will vary, as shown in the typical valve timing diagram (fig. 2-14.) Valve timing is discussed more fully in a later chapter of this book.

When the piston is at TDC the crankshaft can move 15° to 20° without causing the piston to move up and down any noticeable distance. This is one of the two ROCK POSITIONS (fig. 2-15). When the piston moves up on the exhaust stroke, considerable momentum is given to the exhaust gases as they pass out through the exhaust valve port, but if the exhaust valve closes at TDC, a small amount of the gases will be trapped and will dilute the incoming fuel-air mixture when the intake valves open. Since the piston has little downward movement while in the rock position, the exhaust valve can remain open during this period and thereby permit a more complete scavenging of the exhaust gases.

IGNITION TIMING refers to the timing of the spark plug firing with relation to the piston position during the compression and power strokes. The ignition system is timed so that the spark occurs before the piston reaches TDC on the compression stroke. This gives the mixture enough time to ignite and start burning.

If this time were not provided–that is, if the spark occurred at or after TDC–then the pressure increases would take place too late to provide a full power stroke.

At higher speeds, there is still less time for the fuel-air mixture to ignite and burn. In order to compensate for this, and thereby avoid power loss, the ignition system includes both a vacuum and a mechanical advance mechanism that alters ignition timing as engine speed increases. There will be more on this in a later chapter of this manual.

CHAPTER 3

INTERNAL COMBUSTION ENGINES—CONSTRUCTION

In the preceding chapter, you learned how the internal combustion engine operates. You also learned how the basic moving parts of the engine move in a timed relationship to one another during engine operation.

This chapter introduces you to the many stationary parts and provides more information on the moving parts of an internal combustion engine. As a CM, you are concerned with how these parts are made, what materials they are made of, and their relationship to one another in the smooth and efficient operation of the internal combustion engine.

Information is also provided which will enable you to diagnose malfunctions of the engine and to decide what method to use in the correction of these malfunctions. Since gasoline and diesel engines used in today's construction equipment are all basically the same internally, the majority of items covered in this chapter applies to both.

ENGINE CONSTRUCTION

Basic engine construction varies little, regardless of size and design of the engine. The intended use of an engine must be considered before the design and size can be determined. The temperature at which an engine will operate has a great deal to do with determining what metals must be used in its construction.

To simplify the service parts problem in the field, and also to simplify servicing procedures, the present trend in engine construction and design is toward what is called ENGINE FAMILIES. There must, of necessity, be many different kinds of engines because there are many kinds of jobs to be done. However, the service and service parts problem can be simplified by designing engines so that they are closely related in cylinder size, valve arrangement, etc. As an example, the GM series 71 engines can be obtained in 2-, 3-, 4-, and 6-cylinder inline models. GM V-type engines come in 6-, 8-, 12-, and 16-cylinder models. These engines are designed so that many of the internal parts can be used on any of the models.

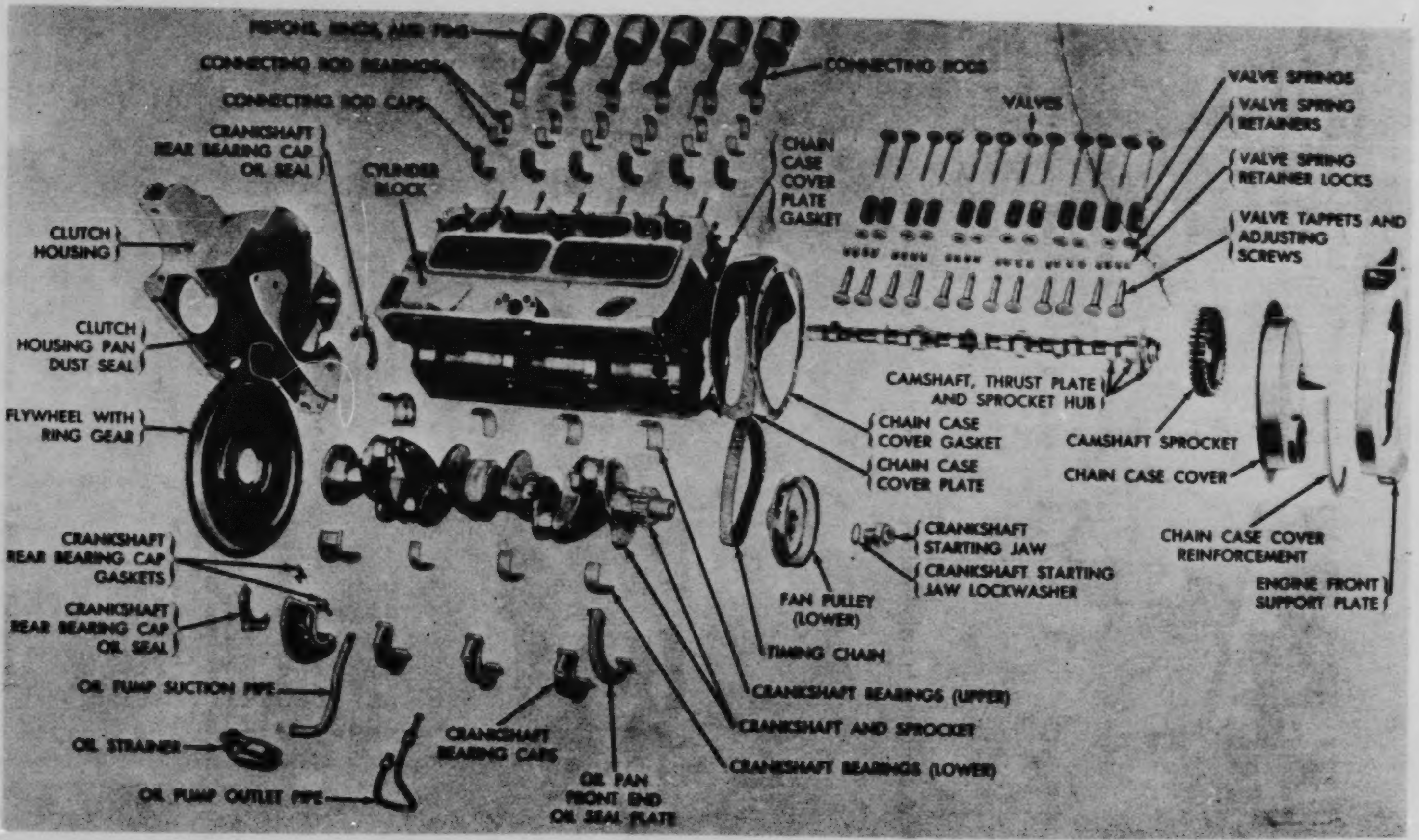
STATIONARY PARTS

The stationary parts of an engine include the cylinder block, cylinders, cylinder head or heads, crankcase, and the exhaust and intake manifolds. These parts furnish the framework of the engine. All movable parts are attached to or fitted into this framework.

ENGINE CYLINDER BLOCK

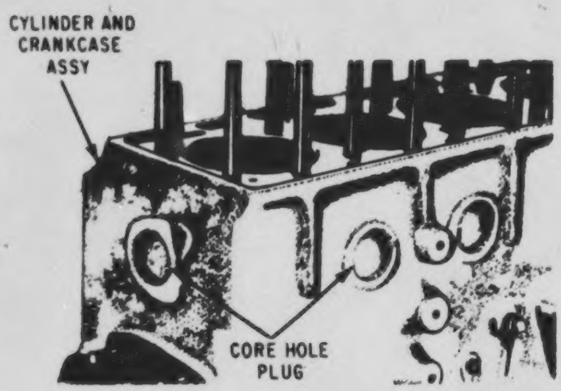
The engine cylinder block is the basic frame of a liquid-cooled engine, whether it be inline, horizontally opposed, or V-type. The cylinder block and crankcase are often cast in one piece; this is the heaviest single piece of metal in the engine. (See fig. 3-1.) In most large diesel engines, such as those used in power plants, the crankcase is cast separately and is attached to a heavy stationary engine base.

In practically all automotive and construction equipment, however, the cylinder block and crankcase are cast in one piece. This type of cylinder block is designated as a cast-en-block or monoblock engine. In this


PISTONS, RINGS, AND PINS
CONNECTING ROD BEARINGS
CONNECTING ROD CAPS
CRANKSHAFT REAR BEARING CAP OIL SEAL
CYLINDER BLOCK
CLUTCH HOUSING
CLUTCH HOUSING PAN DUST SEAL
FLYWHEEL WITH RING GEAR
CRANKSHAFT REAR BEARING CAP GASKETS
CRANKSHAFT REAR BEARING CAP OIL SEAL
OIL PUMP SUCTION PIPE
OIL STRAINER
OIL PUMP OUTLET PIPE
CRANKSHAFT BEARING CAPS
OIL PAN FRONT END OIL SEAL PLATE
CONNECTING RODS
CHAIN CASE COVER PLATE GASKET
VALVES
VALVE SPRINGS
VALVE SPRING RETAINERS
VALVE SPRING RETAINER LOCKS
VALVE TAPPETS AND ADJUSTING SCREWS
CAMSHAFT, THRUST PLATE AND SPROCKET HUB
CHAIN CASE COVER GASKET
CHAIN CASE COVER PLATE
CAMSHAFT SPROCKET
CHAIN CASE COVER
CHAIN CASE COVER REINFORCEMENT
ENGINE FRONT SUPPORT PLATE
CRANKSHAFT STARTING JAW
CRANKSHAFT STARTING JAW LOCKWASHER
FAN PULLEY (LOWER)
TIMING CHAIN
CRANKSHAFT BEARINGS (UPPER)
CRANKSHAFT AND SPROCKET
CRANKSHAFT BEARINGS (LOWER)

81.47

Figure 3-1.—Cylinder block and components.



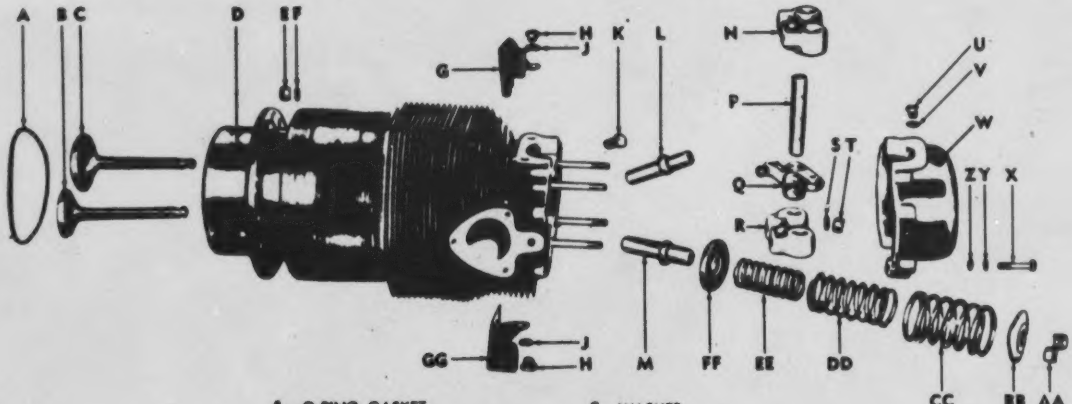
81.509
Figure 3-2.—Core hole plugs installed in cylinder block.

manual we are concerned primarily with monoblock liquid-cooled engines.

The cylinders of a liquid-cooled engine are surrounded by interconnecting passages cast in the block. Collectively these passages form the WATER JACKET, which allows the circulation of coolant through the cylinder block and the cylinder head to carry off the excessive heat created by combustion.

The water jacket is accessible through holes machined in the head and block to allow removal of the material used for the casting of the cylinder block. These holes are called core holes and are sealed by CORE HOLE PLUGS (freeze plugs). These plugs are of two types: cup and disk. Figure 3-2 illustrates typical installation of these plugs.

The air-cooled engine differs from that of a liquid-cooled engine in that the cylinders have



A—O-RING GASKET
B—EXHAUST VALVE
C—INTAKE VALVE
D—CYLINDER
E—CYLINDER BARREL NUT
F—LOCK NUT
G—DOME FIN DEFLECTOR (LH)
H—BOLT
J—LOCK WASHER
K—PRIMER NOZZLE ASSEMBLY
L—INTAKE VALVE GUIDE
M—EXHAUST VALVE GUIDE
N—CAMSHAFT BEARING CAP
P—ROCKER SHAFT
Q—ROCKER
R—ROCKER SUPPORT BRACKET
S—WASHER
T—SLOTTED NUT
U—ROCKER BOX COVER PLATE BOLT
V—TAB WASHER
W—VALVE ROCKER COVER
X—BOLT
Y—LOCK WASHER
Z—WASHER
AA—VALVE LOCK
BB—VALVE SPRING RETAINER
CC—OUTER VALVE SPRING
DD—INTERMEDIATE VALVE SPRING
EE—INNER VALVE SPRING
FF—VALVE SPRING SEAT
GG—DOME FIN DEFLECTOR (RH)

81.48
Figure 3-3.—Cylinder of an air-cooled engine.

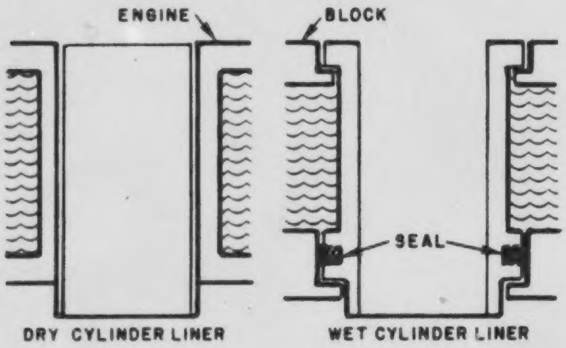
closely spaced fins surrounding the barrel. (See fig. 3-3.) These fins provide a greatly increased surface area from which heat can be dissipated. This is in contrast to the liquid-cooled engine, which has a water jacket around its cylinders.

CYLINDER BLOCK CONSTRUCTION

The cylinder block is cast from gray iron or iron alloyed with other metals such as nickel, chromium, or molybdenum. Some lightweight engine blocks are made from aluminum alloy.

Cylinders are machined by grinding, and/or boring, to give them the desired true inner surface. During normal engine operation, cylinder walls will wear out-of-round, or they may become cracked and scored if not properly lubricated or cooled. LINERS (fig. 3-4) made of metal alloys resistant to wear, are used in many gasoline engines and practically all diesel engines to lessen wear. Liners for 4-stroke cycle engines do not have air inlet ports as shown in figure 3-5. After they have been worn beyond the maximum oversize, the liners can be replaced individually, permitting the use of standard pistons and rings. Thus you can avoid replacing the entire cylinder block.

The liners are inserted into a hole in the block with either a PRESS FIT or a SLIP FIT. Liners are further designated as WET-TYPE or DRY-TYPE. The wet-type liner comes in direct contact with the coolant and is sealed at the top by the use of a metallic sealing ring and at the bottom by a rubber sealing ring; the dry-type liner does not contact the coolant. Special precautions must be taken with the seals when installing a wet-type liner. Use a lubricant on the seals to prevent them from rolling or twisting. Soap or brake fluid is recommended for this purpose. Continued overheating of an engine during operation or improperly installed seals will allow the coolant to enter the crankcase and contaminate the engine oil. To determine which seals are leaking, it is necessary to remove the engine oil pan or inspection covers on the crankcase and pressurize the cooling system, observing the liners through the crankcase for leakage.



81.510
Figure 3-4.—Cylinder liner application.

Cylinder wear is caused by dirt getting through the air cleaner and acting as a grinding compound, by side thrust of the piston, and by pressure of the piston rings against the cylinder walls. Liners, therefore, do not completely prevent wear. To check on wear and to determine how much overhaul is required, use special gages and micrometers to obtain correct measurements. Check the measurements you get with the specifications given in the manufacturer's manual. Most cylinder wall wear occurs at the top of piston travel where pressures are greatest.

Engine blocks for L-head engines contain the passageways for the valves and valve ports. The lower part of the block (crankcase) supports the crankshaft (with main bearings and bearing caps) and also provides a place for fastening the oil pan.

The camshaft is supported in the cylinder block by bushings that fit into machined holes in the block. On L-head inline engines, the intake and exhaust manifolds are attached to the side of the cylinder block.

CYLINDER HEAD

The cylinder head provides the combustion chamber for the engine cylinders. It is built to

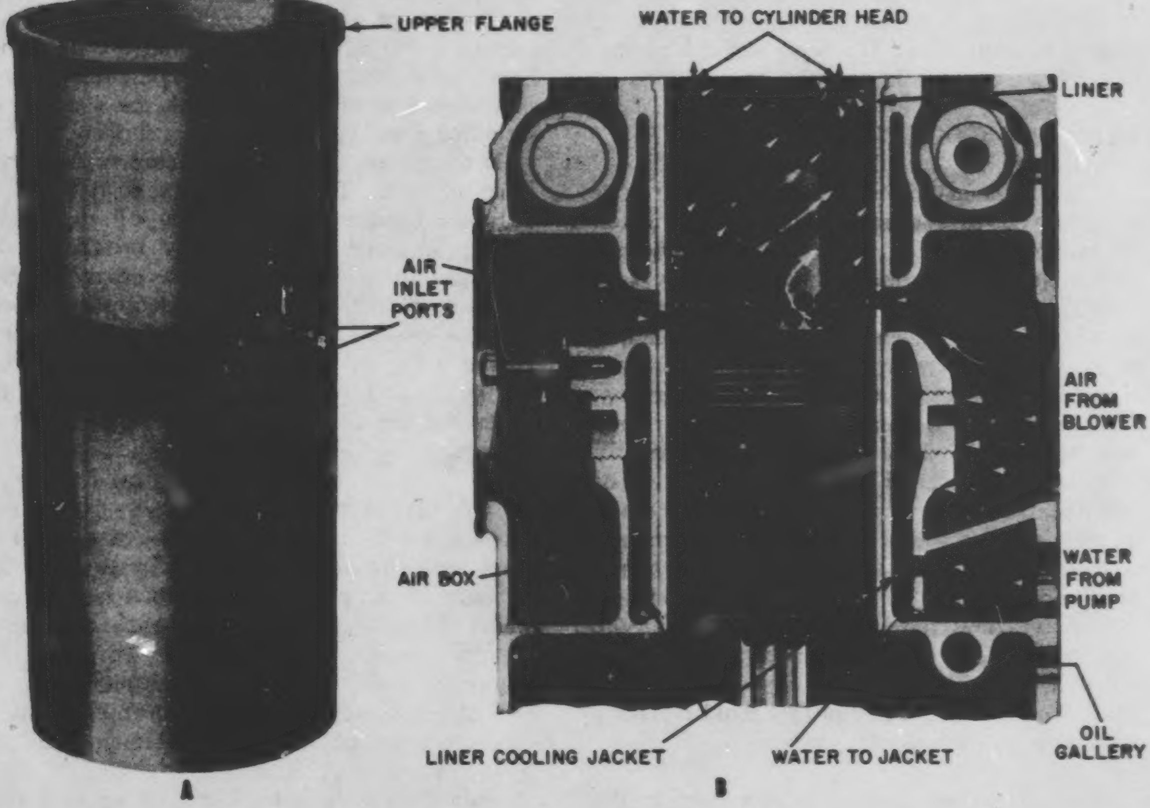


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Figure 3-5.—(A) Dry-type liner for 2-cycle General Motors series engines. (B) Section through series 71 block.

conform to the arrangement of the valves: L-head, I-head, or other. Cylinder heads are usually cast from iron, from iron alloyed with other metals, or from aluminum alloy. Aluminum has the advantage of combining lightness with high heat conductivity. That is, an aluminum head will tend to run cooler, other factors being equal. A high degree of heat conductivity is especially desirable because it assures that the heat of combustion will be rapidly carried away, thus preventing the formation of hot spots which cause preignition (premature ignition of the fuel-air mixture in the cylinder).

In the water-cooled engine the cylinder head (fig. 3-6) is bolted to the top of the cylinder block to close the upper end of the cylinders. It contains passages, matching those of the cylinder block, which allow the cooling water to circulate in the head. The head also helps retain compression in the cylinders. In the gasoline engine there are threaded holes in the cylinder head which lead into the combustion chamber. The spark plugs are screwed into these holes.

In the diesel engine the cylinder head may be cast in a single unit, or may be cast for a single cylinder or two or more cylinders. Separated head sections (usually covering 1, 2, or 3 cylinders in large engines) are easier to handle and can be readily removed. They do not warp easily, are cheaper to replace, and require

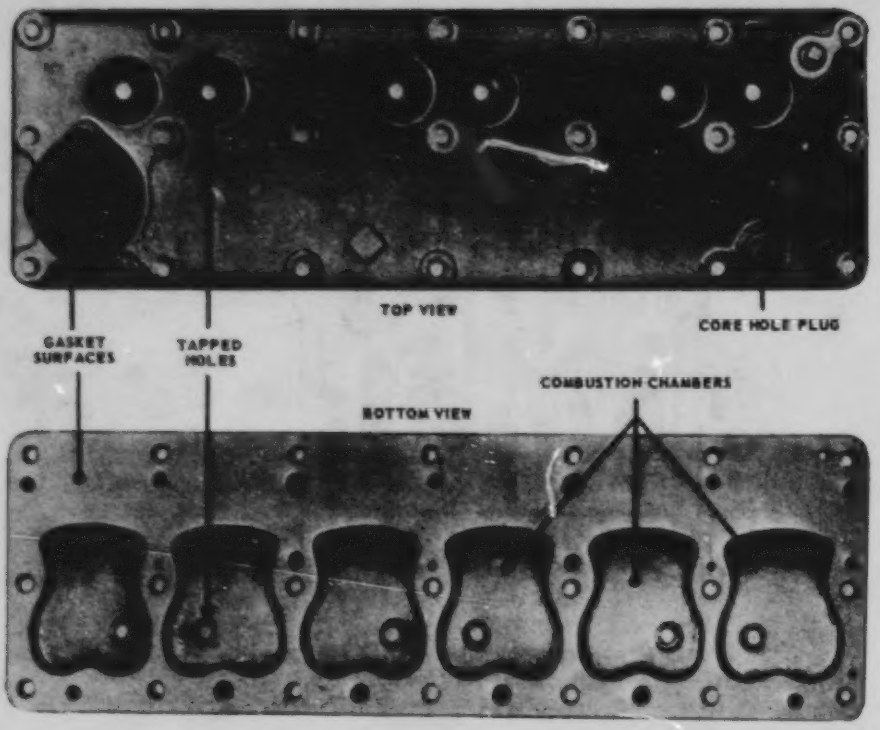

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Figure 3-6.–Cylinder head for L-head engine.

less work for a teardown. Additional information on diesel engine cylinder heads is presented in a later chapter.

The L-head type of cylinder head shown in figure 3-6 is a comparatively simple casting. It contains water jackets for cooling, and openings for spark plugs. Pockets into which the valves operate are also provided. Each pocket serves as a part of the combustion chamber. The air-fuel mixture is compressed in the pocket as the piston reaches the end of the compression stroke. Note that the pockets have a rather complex curved surface. This shape has been carefully designed so that the air-fuel mixture, in being compressed, will be subjected to violent turbulence. This turbulence assures uniform mixing of the fuel and air, thus improving the combustion process.

The I-head (overhead-valve) type of cylinder head (fig. 3-7) contains not only water jackets for cooling spark-plug openings, valve pockets, and part of the combustion chamber, but it also contains and supports the valves and valve operating mechanisms. In this type of cylinder head, the water jackets must be large enough to cool not only the top of the combustion chamber but also the valve seats, valves, and valve-operating mechanisms.

CRANKCASE

The crankcase is that part of the engine block below the cylinders. It supports and encloses the crankshaft and provides a reservoir for the lubricating oil. Oftentimes there are places provided on the crankcase for the mounting of the oil pump, oil filter, starting

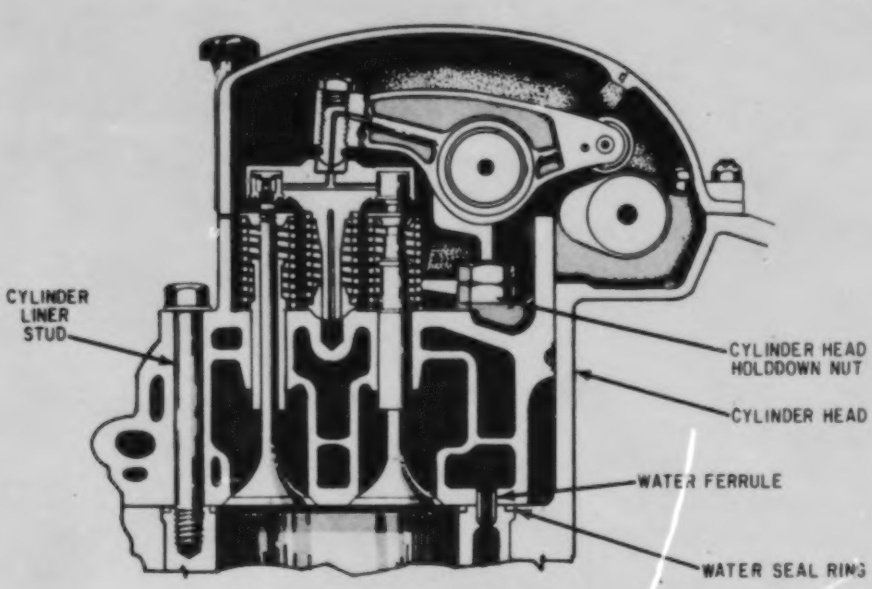

Figure 3-7.—Cylinder head for overhead valve engine.

motor, and the generator. The lower part of the crankcase is the OIL PAN, which is bolted at the bottom. The oil pan may be made of pressed steel or cast metal and holds the lubricating oil for the engine. Since it is the lowest part of the power plant, the oil pan must be strong enough to withstand blows from flying stones and obstructions sticking up from the road surfaces. Checking for dents in the pan and oil leaks is an important part of your job. Get into the habit of checking the spot where the vehicle was parked for water or oil leakage.

The oil pump in the lubricating system draws oil from the oil pan and sends it to working parts in the engine. As the oil drains off and runs down into the pan, it is picked up by the oil pump again and recirculated through the engine.

The crankcase also has mounting brackets which support the entire engine on the vehicle frame. These brackets are either an integral part of the crankcase or are bolted to it in such a way that they support the engine at three or four points. These points of contact usually are cushioned by rubber mounts which insulate the frame and body of the vehicle from engine vibration, and therefore prevent damage to the engine supports and the transmission.

As a result of normal engine operation, water or gasoline may seep down and appear in the crankcase. These liquids evaporate after the engine reaches operating temperature, and the vapors are removed by ventilation.

EXHAUST MANIFOLD

The exhaust manifold is essentially a tube that carriers waste products of combustion from the cylinders. On L-head engines the exhaust manifold is bolted to the side of the engine block; on overhead-valve engines it is bolted to the side of the engine cylinder head. Exhaust manifolds may be single iron castings or may be cast in sections. They have a smooth interior surface with no abrupt changes in size. (See fig. 3-8.)

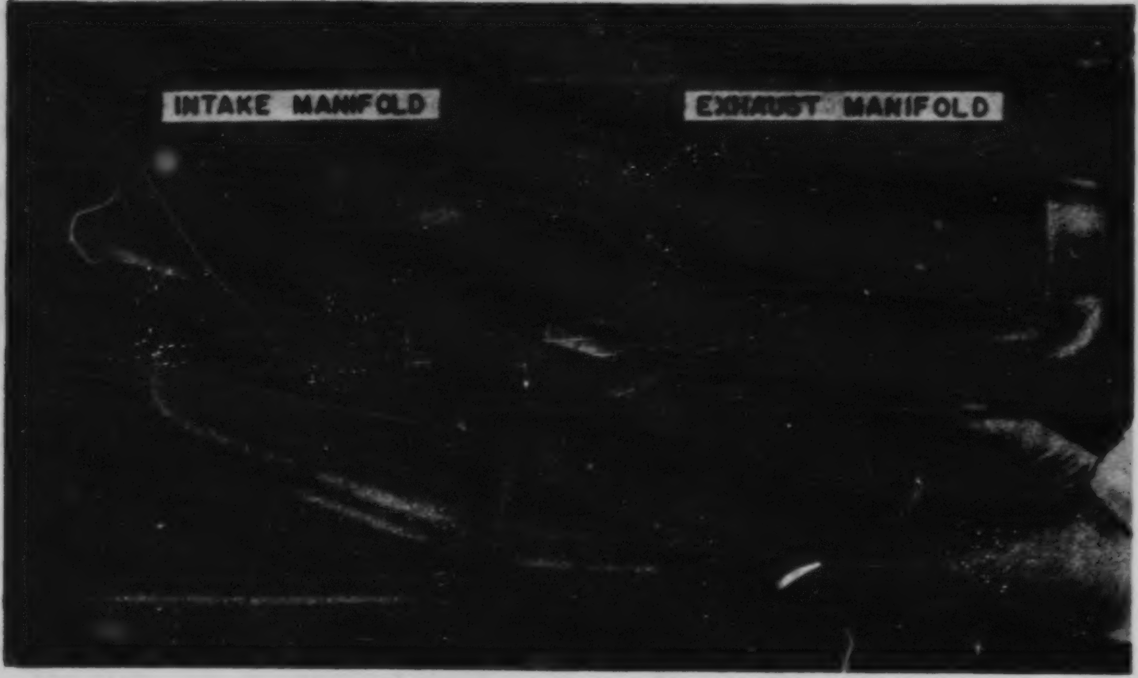

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Figure 3-8.–Intake and exhaust manifolds.

Exhaust manifolds on today's automobiles are constantly changing in design to allow the use of various types of emission controls. The most common type is the large diameter exhaust manifold which is designed for use with the air injection system. Information concerning this type of exhaust manifold is given in chapter 5 of this manual.

INTAKE MANIFOLD

The intake manifold on a gasoline engine carriers the fuel-air mixture from the carburetor and distributes it as evenly as possible to the cylinders. On a diesel engine the manifold carries only air to the cylinders. The intake manifold is attached to the block on L-head engines (fig. 3-8) and to the side of the cylinder head on overhead-valve engines.

In gasoline engines, smooth and efficient engine performance depends largely on whether or not the fuel-air mixtures that enter each cylinder are uniform in strength, quality, and degree of vaporization. The inside walls of the manifold must be smooth to offer little obstruction to the flow of the fuel-air mixture. The manifold is designed to prevent collecting of fuel at the bends in the manifold.

The intake manifold should be as short and straight as possible to reduce the chances of condensation between the carburetor and cylinders. To assist in vaporization of fuel, some intake manifolds are constructed so that part of their surfaces can be heated by hot exhaust gases.

Intake manifolds on today's gasoline powered automobiles have speical passages for allowing exhaust gases to reenter the engine. These intake manifolds are used on engines equipped with an exhaust gas recirculation system.

GASKETS

The principal stationary parts on an engine have just been explained. The gaskets (fig. 3-9) that serve as seals between these parts require as much attention during assembly as any other part. It is impractical to machine all surfaces so that they fit together to form a perfect seal. The gaskets make a sealed joint that will prevent loss of compression, coolant, or lubricant.

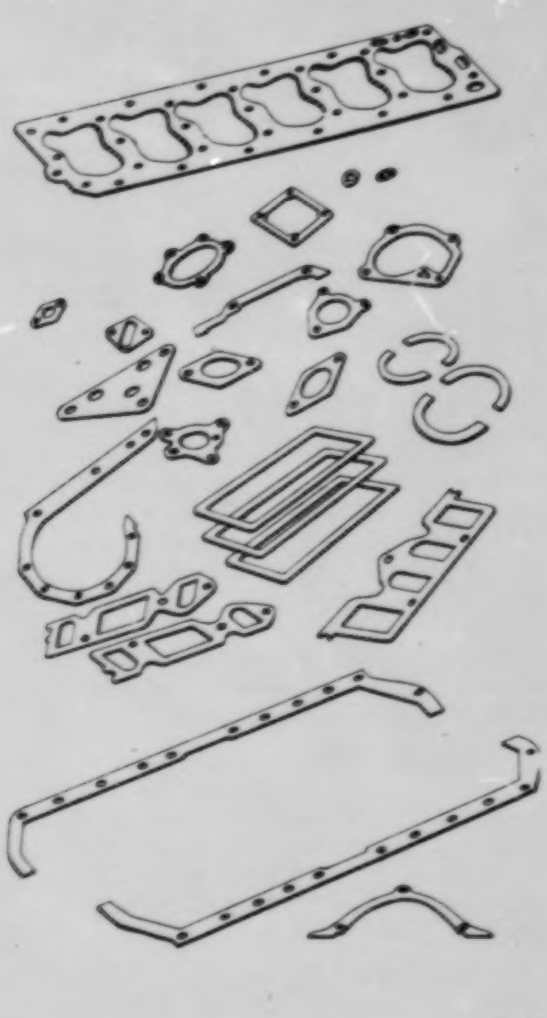

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Figure 3-9.—Engine overhaul gasket kit.

The CYLINDER HEAD GASKET is placed between the cylinder head and engine block to maintain a gastight and coolanttight seal. These gaskets may be metal sheets soft enough to deform as required but they are usually made in the form of two thin plates of soft metal with asbestos filling between them. Holes are punched in the gasket to conform with the openings in the head and block, which allows the cooling water to circulate. If a poorly made or improper gasket is used, the flow of cooling water may be restricted, causing troublesome hot spots.

On some engines, especially V-type, the gaskets are so nearly uniform that they can be turned upside down or end for end and still fit the retaining studs and combustion chambers. If they are improperly installed, however, they will stop water circulation at some parts of the engine. It is important to make sure the correct gasket is used and that the side marked UP or TOP is facing away from the block. If no markings are found, the first surface of the gasket is placed against the block.

The INTAKE AND EXHAUST MANIFOLD GASKETS are usually made from asbestos formed to the desired shape. Some of them are metal covered and similar in construction to a head gasket. Because of the heat of the exhaust and intake air, it is necessary that manifold gaskets be made from a material that will not burn.

The OIL PAN GASKET is generally made from pressed cork. It may be made in one piece but more often it is made in two pieces—one piece for each side of the pan. Each end of the pan is sealed with cork or neoprene gasket material.

The other gaskets for an engine are usually cut from pressed paper that is oil resistant. The thickness of the paper varies in accordance with manufacturer's recommendations. Often the gaskets used will create specified clearances between stationary parts of an engine.

When installing any gasket in an engine, it is important that the surfaces to be sealed be clean and free from grit and parts of the old gasket. A putty knife is useful for cleaning gasket surfaces. You must be sure the gasket is in the proper position and does not slip when the two parts are brought together. Heavy grease or a gasket compound will help you make sure the gaskets stay in place and form a good seal.

SEALS

As explained above, gaskets prevent leaks between stationary parts. As these gaskets are not made to withstand movement of the engine components, we have to use something to prevent loss of liquids as the engine operates. Seals or "O" rings are used to seal the clearances between the moving and stationary parts and the outside of the engine.

Seals manufactured today are too numerous in design to attempt coverage of each particular design in this text. We will mention the more common types and their use only. Most seals you will become familiar with are made of neoprene rubber, molded or crimped to a metal backing. These are known as lip-type seals. The metal seals the outside diameter of the hole it is used in by a press fit. The neoprene, which is flexible and gives a snug fit around the moving part, seals the inside to prevent leakage.

"O" rings, another type of seal, are used primarily in places where the clearance is considerably smaller than with lip-type seals. As the parts are installed, the "O" ring is squeezed to form a tight seal.

On most automotive engines, the rear main seal is a 2-piece strip of molded neoprene rubber, which is squeezed around the rear of the crankshaft between the engine block and rear main bearing cap. This seal works in the same manner as the "O" ring.

As you gain experience in the mechanical field, you will able to recognize the different types of seals and how they work to prevent leaks. In the meantime, if you discover a seal that you have a question about, ask your senior petty officers or the chief. They will be able to explain how seals work and why they are made differently.

MOVING PARTS OF AN ENGINE

The moving parts of an engine serve an important function in turning heat energy into mechanical energy. They further convert reciprocal motion into rotary motion. The principal moving parts are the piston assembly, connecting rods, crankshaft assembly (including flywheel and vibration dampener), camshaft, valves, and gear train.

The burning of the air-fuel mixture within the cylinder exerts a pressure on the piston, thus pushing it down in the cylinder. The action of the connecting rod and crankshaft converts this downward motion to a rotary motion.

PISTON ASSEMBLY

Engine pistons serve a number of purposes: they transmit the force of combustion to the crankshaft through the connecting rod; they act as a guide for the upper end of the connecting rod; and they serve as a carrier for the piston rings used to seal the compression in the cylinder. (See fig. 3-10.) Some pistons are

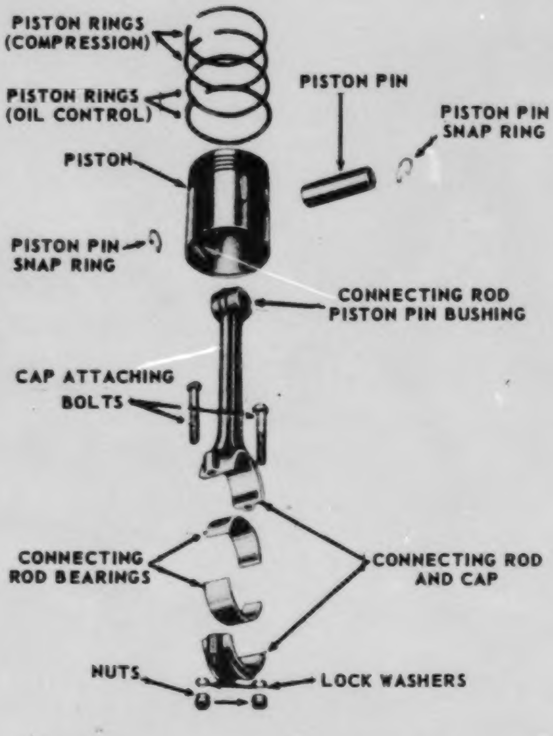

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Figure 3-10.—Piston and connecting rod (exploded view).

designed to cause turbulence in the cylinder in order to mix the air and fuel more efficiently. These pistons are discussed in a later chapter in connection with the diesel fuel system.

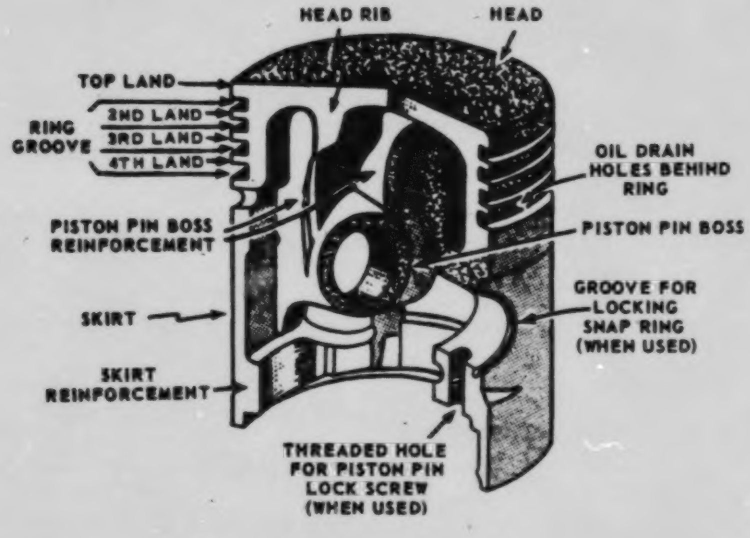
The piston must come to a complete stop at the end of each stroke before reversing its course in the cylinder. To withstand this rugged treatment and wear, it must be made of tough material, yet be light in weight. To overcome inertia and momentum at high speeds, it must be carefully balanced and weighed. All the pistons used in any one engine must be of similar weight to avoid excessive vibration.

Pistons are made of grey cast iron or of aluminum alloy. The former is the heavier and is often used in slower, heavy-duty engines; the latter is of lighter weight and is more adaptable to the modern, high-speed engine. To reduce weight, the head and skirt of the piston are made as thin as is consistent with the strength required. Ribs are an intergral part of the piston which reinforce the head; the ribs also assist in conducting heat from the head of the piston to the piston rings and out through the cylinder walls.

The structural components of the piston are the HEAD, SKIRT, RING GROOVES, and LANDS (fig. 3-11). However, all pistons do not look like the typical one illustrated here. Some have differently shaped heads. Diesel engine pistons usually have more ring grooves and rings than the pistons of gasoline engines. Some of these rings may be installed below as well as above the WRIST or PISTON PIN (fig. 3-12).

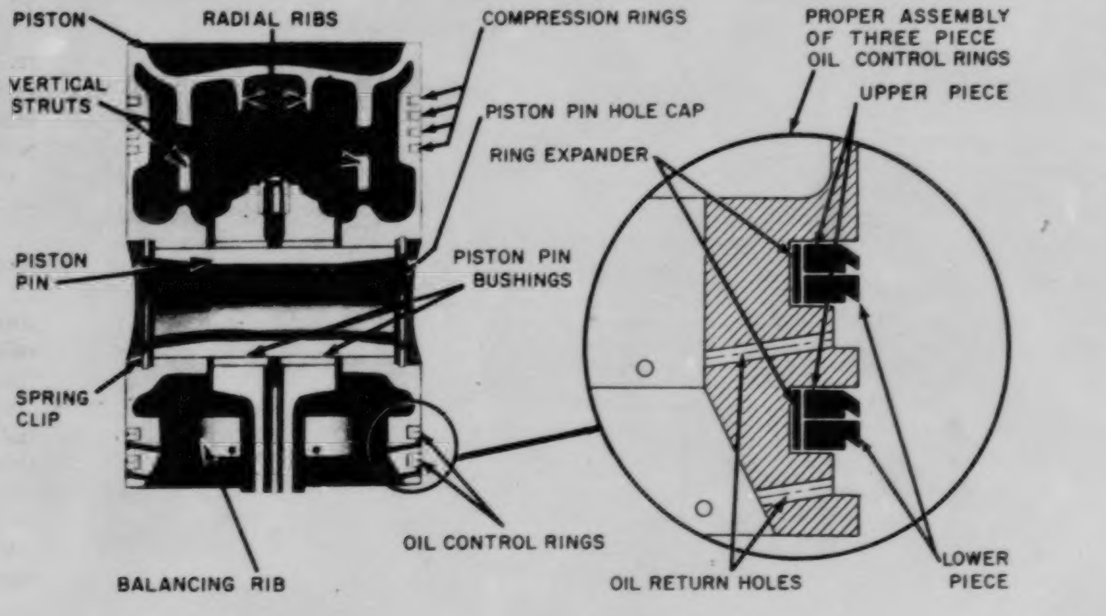
Fitting pistons properly is important. Because metal expands when heated, and because space must be provided for lubricants between the pistons and the cylinder walls, the pistons are fitted to the engine with a specified clearance. This clearance depends upon the size or diameter of the piston and the material from which it is made. Cast iron does not expand as fast or as much as aluminum. Aluminum pistons require more clearance to prevent binding or seizing when the engine gets hot. The skirt or bottom part of the piston runs much cooler than the top; therefore, it does not require as much clearance as the head.

The piston is kept in alinement by the skirt, which is usually CAM GROUND (elliptical in


HEAD RIB
HEAD
TOP LAND
RING GROOVE
2ND LAND
3RD LAND
4TH LAND
OIL DRAIN HOLES BEHIND RING
PISTON PIN BOSS REINFORCEMENT
PISTON PIN BOSS
GROOVE FOR LOCKING SNAP RING (WHEN USED)
SKIRT
SKIRT REINFORCEMENT
THREADED HOLE FOR PISTON PIN LOCK SCREW (WHEN USED)

81.53

Figure 3-11.—The parts of a piston.


PISTON
RADIAL RIBS
COMPRESSION RINGS
PROPER ASSEMBLY OF THREE PIECE OIL CONTROL RINGS
UPPER PIECE
VERTICAL STRUTS
PISTON PIN HOLE CAP
RING EXPANDER
PISTON PIN
PISTON PIN BUSHINGS
SPRING CLIP
OIL CONTROL RINGS
BALANCING RIB
OIL RETURN HOLES
LOWER PIECE

81.54

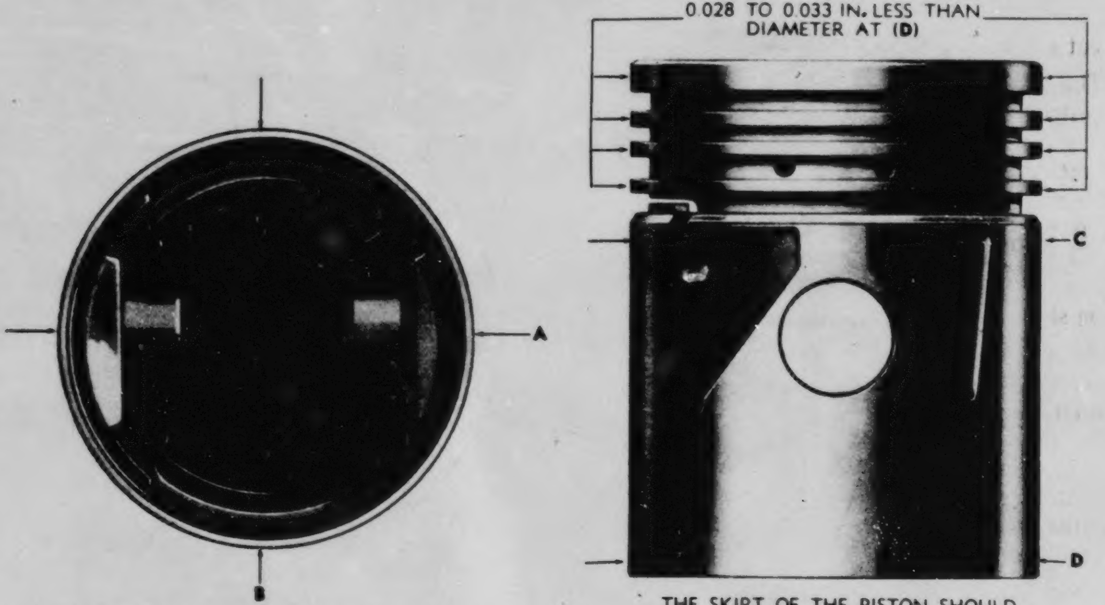
Figure 3-12.–Piston assembly of General Motors series 71 diesel engine.

cross section) as indicated in figure 3-13. This elliptical shape permits the piston to fit the cylinder, regardless of whether the piston is cold or at operating temperature. The narrowest diameter of the piston is at the piston pin bosses, where the metal is thickest. At the widest diameter of the piston, the piston skirt is thinnest. The piston is fitted to close limits at its widest diameter so that piston noise (slap) is prevented during engine warmup. As the piston is expanded by the heat generated during operation, it becomes round because the expansion is proportional to the thickness of the metal. The walls of the skirt are cut away as much as possible to reduce weight and to prevent excessive expansion during engine operation. Many aluminum pistons are made with SPLIT SKIRTS so that when the pistons expand the skirt diameter will not increase.

Two types of piston skirts found in most engines are the FULL TRUNK and the SLIPPER. The full-trunk type skirt has a full cylindrical shape with bearing surfaces parallel to those of the cylinder, giving more strength and better control of the oil film. The SLIPPER TYPE (CUTAWAY) skirt has considerable relief on the sides of the skirt, providing clearance for crankshaft counterweights and leaving less area for possible contact with the cylinder walls and thereby reducing friction.

Piston Pins

The piston is attached to the connecting rod by means of the piston pin (wrist pin). The pin passes through the piston pin bosses and through the upper end of the connecting rod, which rides within the piston on the middle of the pin. Piston pins are made of alloy steel with a precision finish and are case-hardened and sometimes chromium-plated to increase their wearing qualities. Their tubular construction gives them a maximum of strength with a minimum of weight. They are lubricated by splash from the crankcase or by pressure through passages bored in the connecting rods.



THE ELLIPTICAL SHAPE OF THE PISTON SKIRT SHOULD BE 0.010 TO 0.012 IN. LESS AT DIAMETER (A) THAN ACROSS THE THRUST FACES AT DIAMETER (B)

THE SKIRT OF THE PISTON SHOULD TAPER SO THAT THE DIAMETER AT (C) IS FROM 0.0005 TO 0.0015 IN. LESS THAN AT (D).

81.55

Figure 3-13.—Cam-ground piston.

There are three methods commonly used for fastening a piston pin to the piston and the connecting rod. (See fig. 3-14.) An anchored, or fixed, pin is attached to the piston by a screw running through one of the bosses; the connecting rod oscillates on the pin. A semifloating pin is anchored to the connecting rod and turns in the piston pin bosses. A full-floating pin is free to rotate in the connecting rod and in the bosses, but is prevented from working out against the sides of the cylinder by plugs or snapring locks.

Piston Rings

Piston rings are used on pistons to maintain gastight seals between the pistons and cylinders, to assist in cooling the piston, and to control cylinder-wall lubrication. About one-third of the heat absorbed by the piston passes through the rings to the cylinder wall. Although piston rings have been made from many materials, cast iron has proved the most satisfactory, as it withstands heat, forms a good wearing surface, and retains a great amount of its elasticity after considerable use. Piston rings are often quite complicated in design, are heat treated in various ways, and are plated with other metals. There are two distinct classifications of piston rings: compression rings and oil control rings. (See fig. 3-15.)

The principal function of a compression ring is to seal in the air-fuel mixture as it is compressed and also seal in the combustion pressures as the mixture burns during the compression and power strokes. All piston rings are split to permit assembly to the piston and to allow for expansion. When the ring is in place, the ends of the split joint do not form a perfect seal; therefore, it is necessary to use more than one ring and to stagger the joints around the piston. If cylinders are worn, expanders (figs. 3-12 and 3-15) are sometimes used to insure a perfect seal.

The bottom ring, usually located just above the piston pin, is an oil-regulating ring. This ring scrapes the excess oil from the cylinder walls and returns some of it, through slots, to the piston ring grooves. The ring groove under an oil ring is provided with openings through which the oil flows back into the crankcase. In some engines, additional oil rings are used in the piston skirt below the piston pin.

Prior to installing a new ring, first fit it, proper side up, by pushing it part way into the cylinder. By using the top of the piston as a guide, the ring will be located in the proper plane in the cylinder. Check the gap between the ends of the ring. Clearances are specified in the manufacturer's manual and should be carefully adhered to.

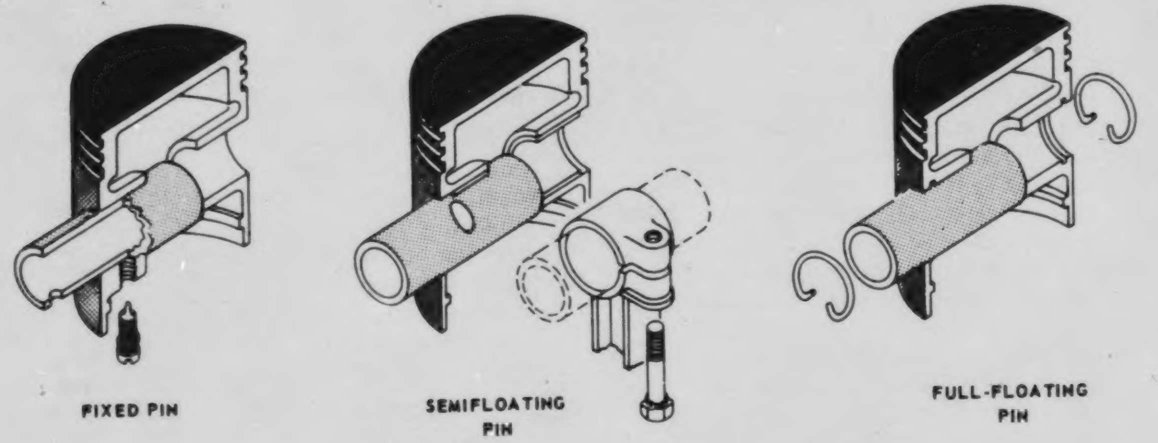
Rings must be fitted also for the proper side clearance. (See fig. 3-16.) This clearance will vary in different types and makes of engines; however, in the diesel engine the rings must be given a greater clearance than in the gasoline engine. If too much side clearance is given the rings, excessive wear on the lands will result. If there is too little side clearance, expansion may cause the lands to break.

CONNECTING RODS

Connecting rods must be light and yet strong enough to transmit the thrust of the pistons to the crankshaft. Connecting rods are drop-forged from a steel alloy capable of withstanding heavy loads without bending or twisting. Holes at the upper and lower ends are machined to permit accurate fittings of bearings. These holes must be parallel.

The upper end of the connecting rod is connected to the piston by the piston pin. If the piston pin is locked in the piston pin bosses, or if it floats in both piston and connecting rod, the upper hole of the connecting rod will have a solid bearing (bushing) of bronze or similar material. As the lower end of the connecting rod revolves with the crankshaft, the upper end is forced to turn back and forth on the piston pin. Although this movement is slight, the bushing is necessary because the temperatures and the pressures are high. If the piston pin is semifloating, a bushing is not needed.

The lower hole in the connecting rod is split to permit it to be clamped around the crankshaft. The bottom part, or cap, is made of the same material as the rod and is attached by two or more bolts. The surface that bears on the crankshaft is generally a bearing material in the



FIXED PIN

SEMIFLOATING PIN

FULL-FLOATING PIN

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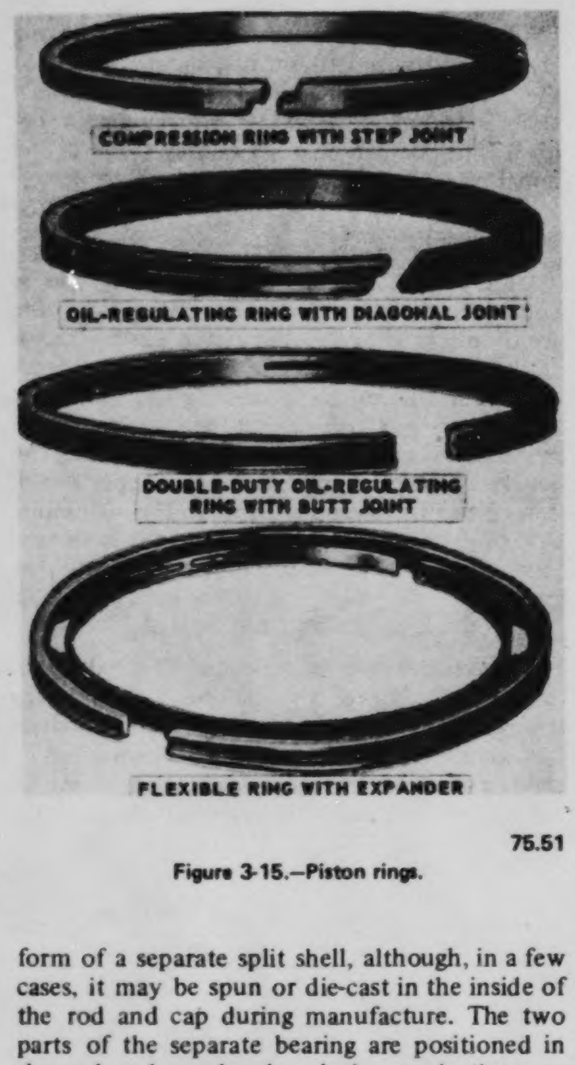
Figure 3-14.—Piston pin types.

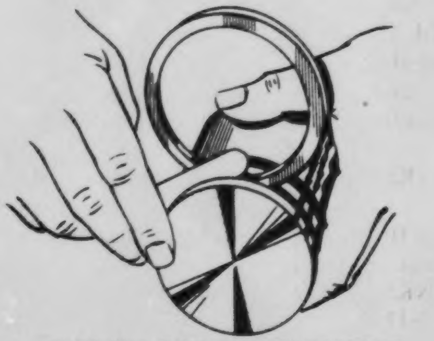

COMPRESSION RING WITH STEP JOINT
OIL-REGULATING RING WITH DIAGONAL JOINT
DOUBLE-DUTY OIL-REGULATING RING WITH BUTT JOINT
FLEXIBLE RING WITH EXPANDER

75.51

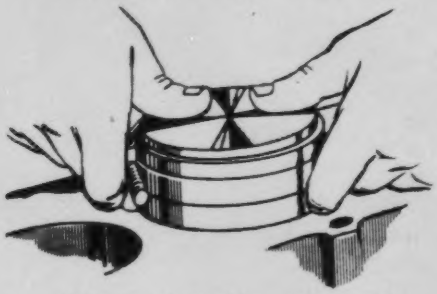
Figure 3-15.—Piston rings.

form of a separate split shell, although, in a few cases, it may be spun or die-cast in the inside of the rod and cap during manufacture. The two parts of the separate bearing are positioned in the rod and cap by dowel pins, projections, or short brass screws. The shell may be of babbitt metal that is die-cast on a backing of bronze or steel. Split bearings may be of the precision or semiprecision type.

The PRECISION type bearing is accurately finished to fit the crankpin and does not require further fitting during installation. It is positioned by projections on the shell which match reliefs in the rod and cap. The projections prevent the bearings from moving sideways and from rotary motion in the rod and cap.



CHECKING RING SIDE CLEARANCE



INSTALLING PISTON AND RINGS

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Figure 3-16.—Fitting piston ring and installing piston.

The SEMIPRECISION type bearing is usually fastened to or die-cast with the rod and cap. Prior to installation, it is machined and fitted to the proper inside diameter with cap and rod bolted together.

To maintain good engine balance, connecting rods are carefully matched in sets. When it becomes necessary to remove the connecting rods, make sure they are marked so they can be replaced in the same cylinder from which they were removed. Most rods are marked at the factory, but if they are not, use a center punch or hacksaw to mark them in such a way that you will not get them mixed.

In addition to the proper fit of the connecting rod bearings and the proper position of the connecting rod, the alinement of the rod itself must be considered. That is to say, the hole for the piston pin and the crankpin must be precisely parallel. Equipment of suitable accuracy is available for checking connecting rods. (See fig. 3-17.) EVERY connecting rod should be checked for proper alinement just before it is installed in the engine. Misalinement of connecting rods will cause many hard-to-locate noises in the engine.

CRANKSHAFT

As the pistons collectively might be regarded as the heart of the engine, so the CRANKSHAFT may be considered its backbone (fig. 3-18). It ties together the reactions of the pistons and the connecting rods, transforming; their reciprocating motion into a rotary motion. and it transmits engine power through the flywheel, clutch, transmission, and differential to drive your vehicle.

The crankshaft is forged or cast from an alloy of steel and nickel, is machined smooth to provide bearing surfaces for the connecting rods and the main bearings, and is CASEHARDENED, or coated in a furnace with copper alloyed with carbon. These bearing surfaces are called JOURNALS. The crankshaft counterweights impede the centrifugal force of the connecting rod assembly attached to the THROWS or points of bearing support. These throws must be placed so that they counterbalance each other.

Crank throw arrangements for 4-, 6-, and 8-cylinder engines are shown in figure 3-19. Four-cylinder engine crankshafts have either three or five main support bearings and four throws in one plane. In figure 3-19 you see that the throws for No. 1 and No. 4 cylinders (4-cylinder engine) are 180° from those for No. 2 and No. 3 cylinders. On 6-cylinder engine crankshafts, each of the three pairs of throws is arranged 120° from the other two. Such crankshafts may be supported by as many as seven main bearings; that is, one at each end of the shaft and one between each of the crankshaft throws. The crankshafts of 8-cylinder V-type engines are similar to those for the 4-cylinder inline type or may have each of the four throws fixed at 90° from each other (as in fig. 3-19) for better balance and smoother operation.

V-type engines usually have two connecting rods fastened side by side on one crankshaft throw. With this arrangement one bank of the engine cylinders is set slightly ahead of the other to allow the two rods to clear each other.

Any piece of rotating machinery has a CRITICAL SPEED at which it will vibrate.

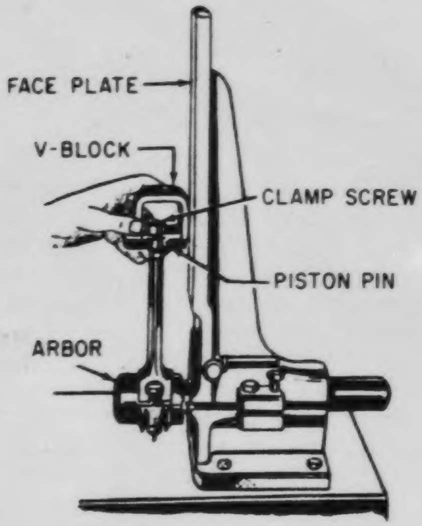

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Figure 3-17.—Checking connecting rod alignement.

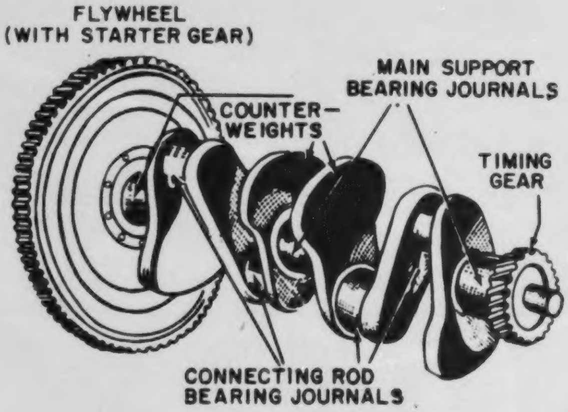
FLYWHEEL (WITH STARTER GEAR)
MAIN SUPPORT BEARING JOURNALS
COUNTER-WEIGHTS
TIMING GEAR
CONNECTING ROD BEARING JOURNALS

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Figure 3-18.—Crankshaft of a 4-cylinder engine.

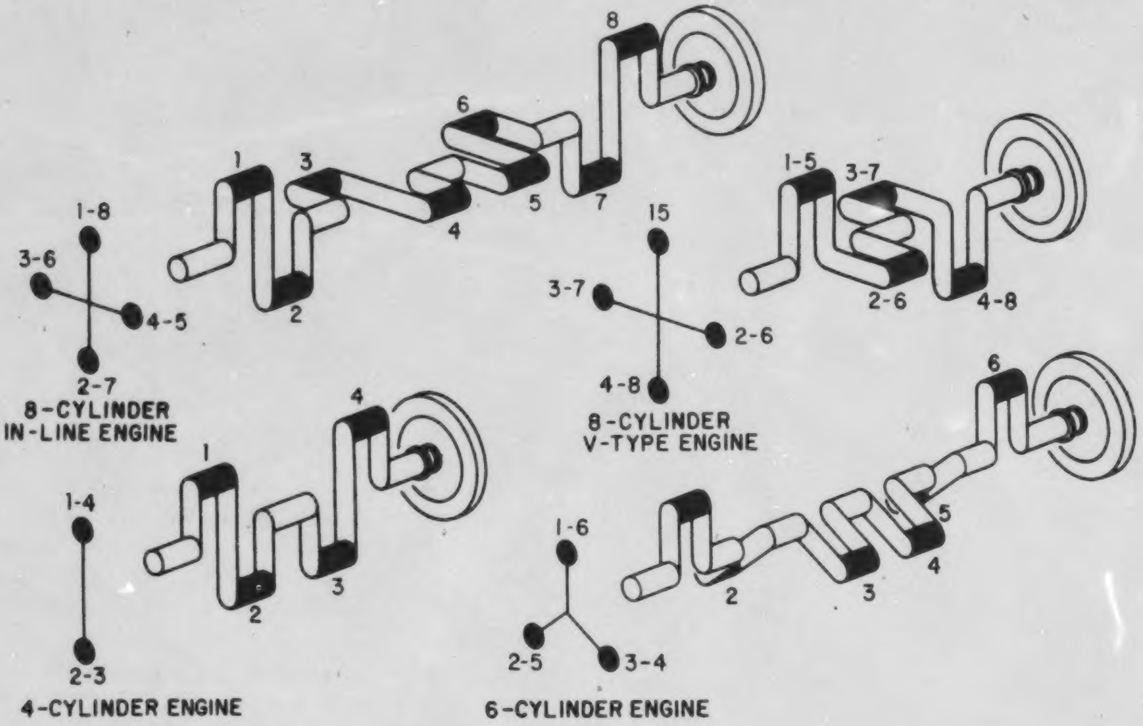

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Figure 3-19.—Crankshaft and throw arrangements commonly used.

Thus, the thrust of power described in the preceding paragraphs creates a torsional or twisting vibration of the crankshaft. Torsional vibration is noticeable in long crankshafts, and unless it is controlled, the crankshaft could break. If you can imagine a rubber tube being twisted by a forceful turn of a wheel to which it is connected, you can visualize a similar characteristic in the crankshaft (only to a much lesser degree) as it begins to turn against the inertia of the flywheel.

The crankshaft rotates in MAIN bearings located at both of its ends and at certain intermediate points. Most crankshaft bearings are precision bearings (prefit) that consist of a hard shell of steel or bronze, with a thin lining of antifrictional metal or bearing alloy. These bearings often are channeled for oil distribution and may be lubricated with crankcase oil by pressure through drilled passages or by splash. Some main bearings have integral thrust faces that eliminate crankshaft end play. To prevent loss of oil, seals are placed at both ends of the crankshaft where it extends through the crankcase. Similar seals are placed in the channels provided in the upper half of the bearings. When replacing main bearings, tighten the bearing-cap bolts to the proper tension with a torque wrench and lock them with a cotter pin or safety wire after they are in place.

Engine crankshafts are large and expensive; therefore, it is often desirable to repair them rather than replace them. An engine crankshaft is subjected to terrific stresses and it may develop minute cracks. Before extensive repair work is started, check the shaft carefully for cracks, particularly near the ends of the connecting rod throws, near the ends of the main bearing journals, and near the oil feed holes. If the shaft is sound, the bearing journals may be reground and undersize bearings fitted. A First Class Petty Officer or Chief will generally be the one who makes the final decision whether to repair or to replace a crankshaft.

Vibration Damper

The power impulses of an engine tend to set up torsional vibration in the crankshaft. If this torsional vibration were not controlled, the crankshaft might actually break at certain speeds; a vibration damper mounted on the front of the crankshaft is used to control this vibration.

Most types of vibration dampers resemble a miniature clutch. (See fig. 3-20.) A friction facing is mounted between the hub face and a small damper flywheel. The damper flywheel is mounted on the hub face with bolts that go through rubber cones in the flywheel. These cones permit limited circumferential movement between the crankshaft and damper flywheel. This minimizes the effects of the torsional vibration in the crankshaft. Several other types of vibration dampers are used. However, they all operate in essentially the same way.

Engine Flywheel

The flywheel is mounted at the rear of the crankshaft near the rear main bearing. This is usually the longest and heaviest main bearing in the engine, as it must support the weight of the flywheel.

The flywheel (fig. 3-21) stores up energy of rotation during power impulses of the engine. It releases this energy between power impulses, thus assuring fewer fluctuations in engine speed and smoother engine operation. The size of the flywheel will vary with the number of cylinders and the general construction of the engine. With a large number of cylinders and the consequent overlapping of power impulses, there is less need for a flywheel; consequently, the flywheel can be relatively small. The flywheel rim carries a ring gear, either integral with the flywheel or shrunk on. By heating the ring gear, putting it in place, and then allowing it to cool and contract on the flywheel, the ring gear meshes with the

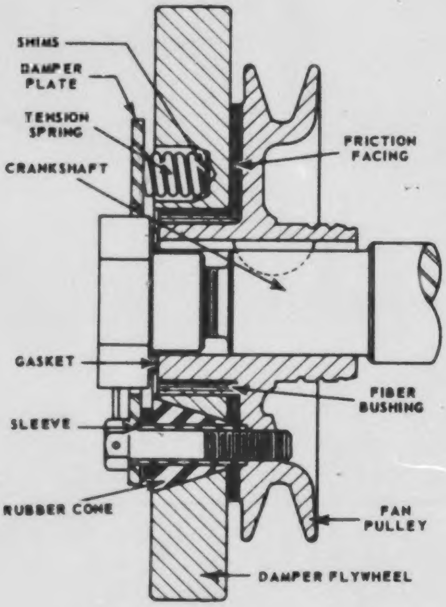

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Figure 3-20.—Section view of a typical vibration damper.

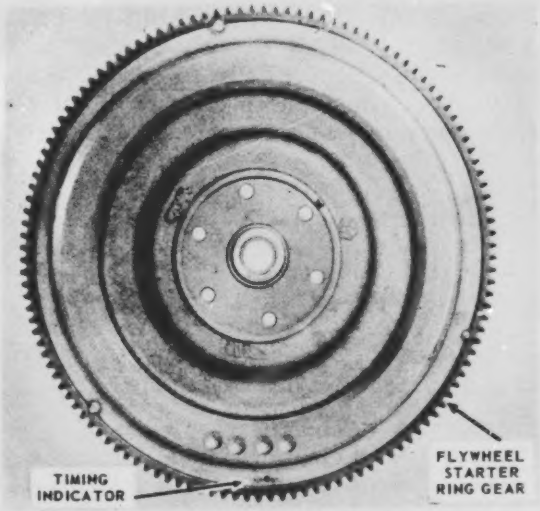

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Figure 3-21.—Flywheel.

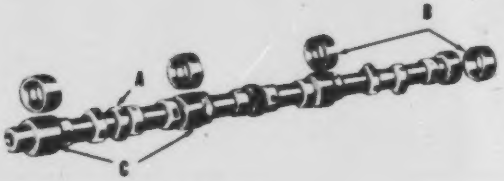
starter driving gear for cranking the engine. The rear face of the flywheel is usually machined and ground, and acts as one of the pressure surfaces for the clutch, becoming a part of the clutch assembly.

VALVES AND VALVE MECHANISMS

There are two valves for each cylinder in most engines, one intake and one exhaust valve. Since each of these valves operates at different times, it is necessary that separate operating mechanisms be provided for each valve. Valves are normally held closed by heavy springs and by compression in the combustion chamber. The purpose of the valve-actuating mechanism is to overcome the spring pressure and open the valve at the proper time. The valve-actuating mechanism includes the engine camshaft, camshaft followers (tappets), pushrods, and rocker arms.

Camshaft

The camshaft (fig. 3-22) is enclosed in the engine block. It has eccentric lobes (cams) ground on it for each valve in the engine. As the camshaft rotates, the cam lobe moves up under the valve tappet, exerting an upward thrust through the tappet against the valve stem or a pushrod. This thrust overcomes the valve spring pressure as well as the gas pressure in the cylinder causing the valve to open. When the lobe moves from under the tappet, the valve spring pressure reseats the valve.



A - Camshaft
B - Camshaft Bearings
C - Bearing Journal

81.61
Figure 3-22.—Camshaft and bushings.

On L-, F-, or I-head engines, the camshaft is usually located to one side and above the crankshaft, while in V-type engines it is usually located directly above the crankshaft. On the overhead camshaft engine, such as the 1 1/4 ton cargo, the camshaft is located above the cylinder head.

The camshaft of a 4-stroke cycle engine turns at one-half engine speed. It is driven off the crankshaft through timing gears or a timing chain. (The system of camshaft drive will be explained later in this chapter.) In the 2-stroke cycle engine the camshaft must turn at the same speed as the crankshaft in order that each valve may open and close once in each revolution of the engine.

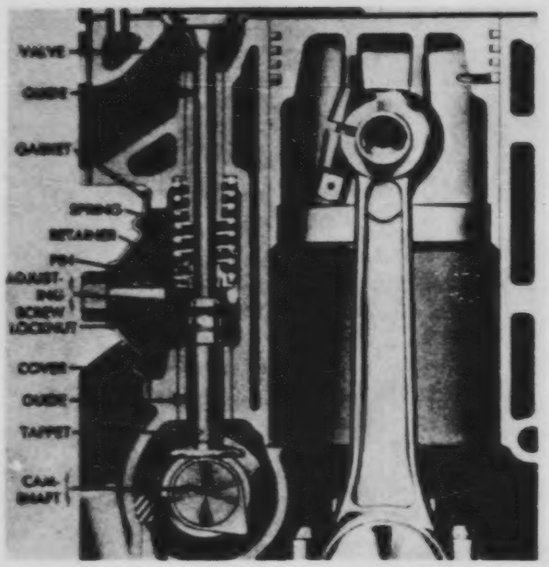
In most cases the camshaft will do more than operate the valve mechanism. It may have extral cams or gears that operate fuel pumps, fuel injectors, the ignition distributor, or the lubrication pump.

Camshafts are supported in the engine block by journals in bearings. Camshaft bearing journals are the largest machined surfaces on the shaft. The bearings are usually made of bronze and are bushings rather than split bearings. The bushings are lubricated by oil circulating through drilled passages from the crankcase. The stresses on the camshaft are small, therefore, the bushings are not adjustable and require little attention. The camshaft bushings are generally replaced only when the engine requires a complete overhaul.

Followers

Camshaft followers are the parts of the valve-actuating mechanism that contact the camshaft. You will probably hear them called valve tappets or valve lifters. In the L-head engine the followers or tappets directly contact the end of the valve stem and have an adjusting device in them (fig. 3-23). In the overhead valve engine, the followers or valve tappets contact the pushrod that operates the rocker arm (fig. 3-24). The end of the rocker arm opposite the pushrod contacts the valve stem. The valve adjusting device, in this case, is in the rocker arm.

Many engines have self-adjusting valve lifters of the hydraulic type that operate at zero clearance at all times. The operation of one type of hydraulic valve tappet mechanism is shown in figure 3-25. Oil under pressure is forced into the tappet when the valve is closed, and this pressure extends the plunger in the tappet so that all valve clearance, or lash, is eliminated. When the cam lobe moves around under the tappet and starts to raise it, there will not be any tappet noise. As the lobe starts to raise the tappet, the oil is forced upward in the lower chamber of the tappet. This action closes the ball check valve so oil cannot escape. Then the tappet acts as though it were a simple, one-piece tappet and the valve is opened. When the lobe moves out from under the tappet and the valve closes, the pressure in the lower chamber of the tappet is relieved. Any slight loss of oil from the lower chamber is then replaced by the oil pressure from the engine lubricating system. This causes the plunger to move up snugly against the pushrod so that any clearance is eliminated.



81.64

Figure 3-23.–L-head valve operating mechanism.

Engine Valves and Valve Seats

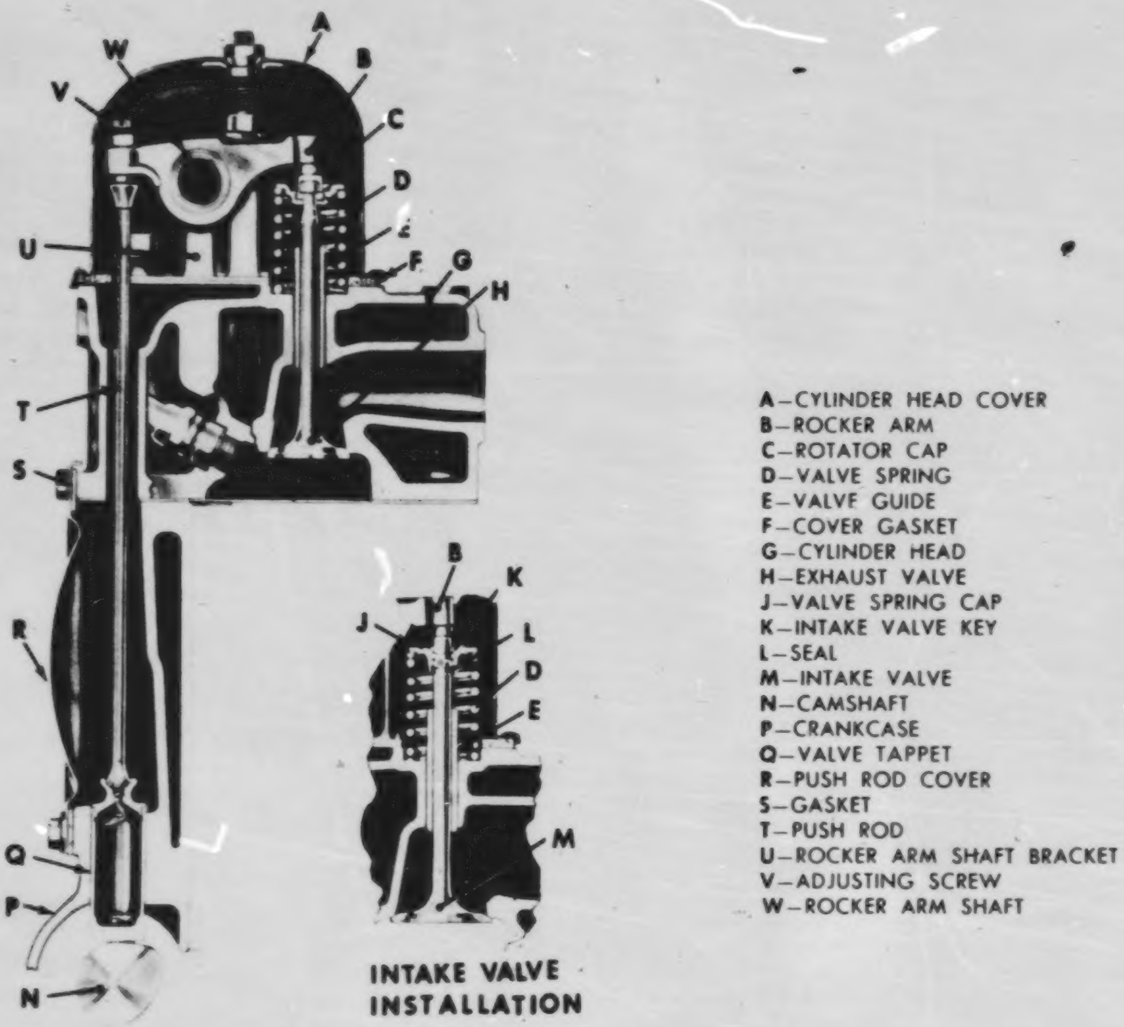
Most engines have POPPET VALVES (also called MUSHROOM or TULIP VALVES). The word "poppet" comes from the popping action of the valve; "mushroom" and "tulip" come from the shape of the valve. The intake valves are ordinarily made of chromium-nickel alloy. The exhaust valves are generally made of silichrome alloy because of the extremely high temperatures they must withstand. Sometimes exhaust valves contain sodium in a sealed cavity extending from head to stem. This sodium cools the valves by conducting heat away from it.

Both the intake and the exhaust valves operate against the rims of circular openings (valve ports) in the combustion chambers of the cylinders. These rims are called VALVE SEATS (fig. 3-26). The valve and valve seat must make perfect contact. Although some earlier engines were designed with flat contact surface for the valve and valve seat, most are now designed with valve seat angles of 30 to 45 degrees as shown in figure 3-26. This angle helps prevent excessive accumulation of carbon on the contact surface of the seat, a condition which keeps the valve from closing properly. To further reduce carbon buildup an interference angle, usually 1° between the valve and seat, is used on some engines. Carbon deposits, incidentally, tend to pit the softer metal of the cylinder block and head.

Many engines have replaceable VALVE SEAT INSERTS (fig. 3-27) made of special heat resistant alloys. These inserts can be used in either cast-iron or aluminum blocks or heads. When a valve seat insert is badly worn from grinding or pitting, it must be replaced.

Reconditioning Valves and Valve Seats

Valve reconditioning includes grinding valves and valve seats, adjusting valve tappet clearances, installing new seat inserts, and timing the valves. Together these operations constitute the VALVE SERVICE necessary for smooth engine performance and maximum power output.



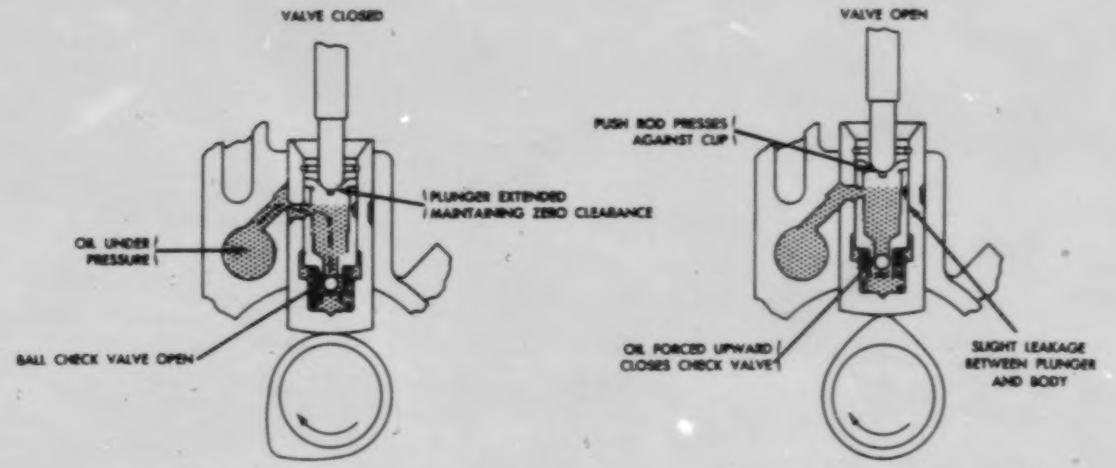
A–CYLINDER HEAD COVER
B–ROCKER ARM
C–ROTATOR CAP
D–VALVE SPRING
E–VALVE GUIDE
F–COVER GASKET
G–CYLINDER HEAD
H–EXHAUST VALVE
J–VALVE SPRING CAP
K–INTAKE VALVE KEY
L–SEAL
M–INTAKE VALVE
N–CAMSHAFT
P–CRANKCASE
Q–VALVE TAPPET
R–PUSH ROD COVER
S–GASKET
T–PUSH ROD
U–ROCKER ARM SHAFT BRACKET
V–ADJUSTING SCREW
W–ROCKER ARM SHAFT

81.65

Figure 3-24.–Valve operating mechanism for an overhead valve engine.

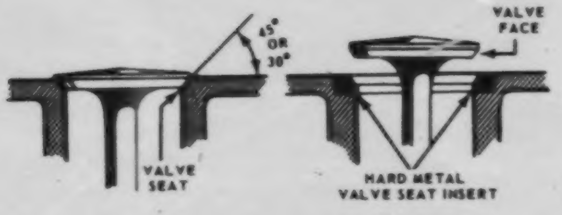
"Grinding valves" is a common expression used around the shop. It is the major, but not the only, operation in reconditioning them. Before valves are ground or refaced on the valve-refacing machine, they must be cleaned. Heavy carbon deposits and excessively burned valves may indicate the need for new rings or valve guides and/or intake valve oil seals. Carbon deposits and burned valves may also indicate improper combustion resulting from poor spark ignition in the gasoline engine or improper fuel injection in the diesel engine.

To recondition valves and valve seats, first take off the cylinder head and remove the carbon from the head, cylinder block, and pistons. In cleaning the top of the pistons, you must exercise care to prevent gouging and


VALVE CLOSED
PLUNGER EXTENDED MAINTAINING ZERO CLEARANCE
OIL UNDER PRESSURE
BALL CHECK VALVE OPEN
VALVE OPEN
PUSH ROD PRESSES AGAINST CUP
OIL FORCED UPWARD CLOSES CHECK VALVE
SLIGHT LEAKAGE BETWEEN PLUNGER AND BODY

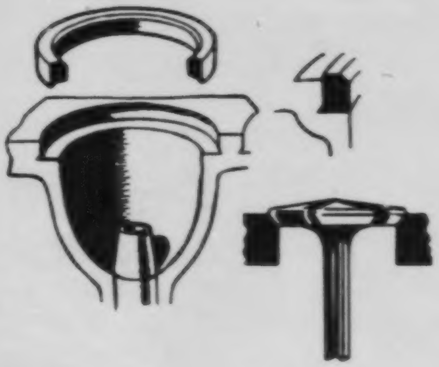
81.66

Figure 3-25.—Operation of a hydraulic valve tappet or lifter.


45° OR 30°
VALVE FACE
VALVE SEAT
HARD METAL VALVE SEAT INSERT

75.75

Figure 3-26.—Valve Head and set angle.



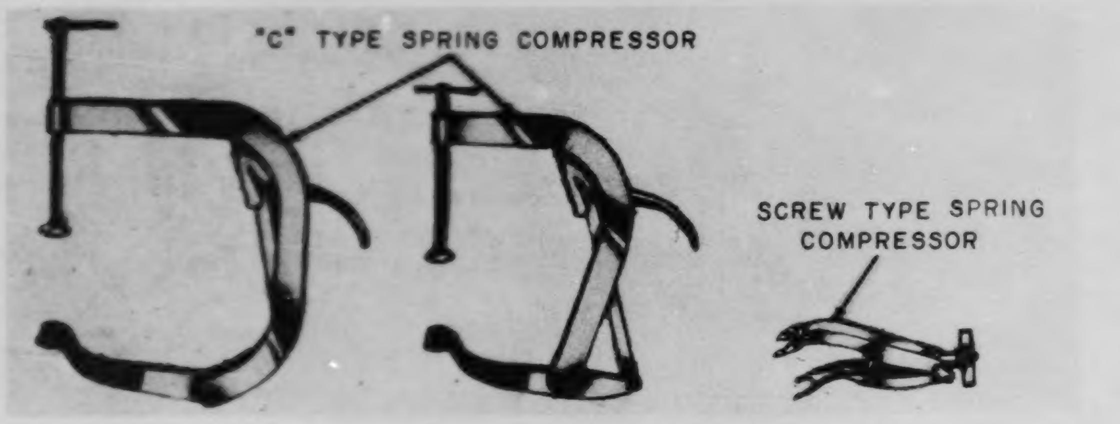
81.67

Figure 3-27.—Valve seat insert.

scratching, as rough spots collect carbon readily and will lead to preignition and detonation during engine operation. Remove the valves, using a valve spring compressor (fig. 3-28). Next, clean the valves with a wire brush or buffing wheel (fig. 3-29). When using the buffing wheel, make sure you wear proper eye protection to prevent wire and other foreign matter from flying into your eyes.

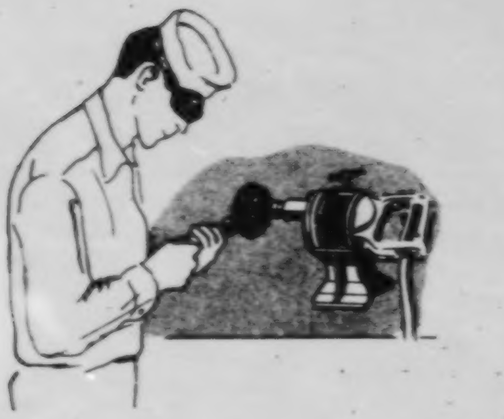
Be careful not to interchange the valves. Each valve must be replaced in the same valve port from which it was removed. The valve stem moving up and down in the valve guide develops a wear pattern. And, if the valves are interchanged, a new wear pattern is developed causing excessive wear on the valve stem and guide.

To eliminate any confusion, you should devise some system of marking the valves to identify them with the cylinders from which they were taken. The most common way to identify valves is to place them in a piece of board with holes drilled and numbered to



81.10X

Figure 3-28.—Valve spring compressors for L-head and valve-in-head engines.



81.68

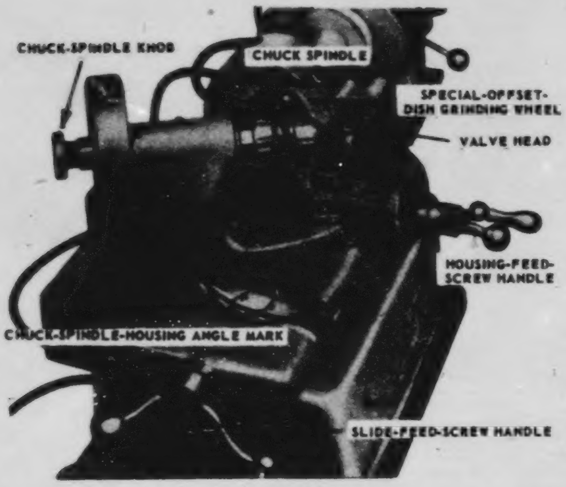
Figure 3-29.—Cleaning a valve with a wire buffing wheel.

correspond with the cylinder the valves came from. If any valves are found to be worn or damaged beyond use during inspection, replace them with new ones from the parts room.

After you have cleaned the valves, remove the carbon from the intake and exhaust valve ports. Inspect closely around the valve ports and cylinders of the block for cracks and faulty valve seats. Should cracks be found, check with your supervisor for the proper procedure to follow. After you inspect the cylinder head for cracks, check the head for warpage, using a straightedge and a thickness gage. The water passages inside the head should be cleaned if an excessive buildup of scale and rust is found. The easiest method is to remove the core plugs and boil the head in a cleaning solution. The alternate method is to scrape the unwanted material loose and then flush with water, air, or a combination of both. After a thorough inspection of the parts, the next step is to resurface the valve face with a valve refacing machine (fig. 3-30). Clamp the valve stem in the chuck of the refacing machine. Be sure the grinding angle index is set to the angle of the valve head you are about to grind. Follow the operating instructions of the manufacturer of the refacing machine together with those of your Chief while becoming familiar with the details of grinding.

If the tip ends of the valve stems are rough, smooth them by grinding lightly with a special attachment furnished with the valve refacing machine.

Before the valve seats are serviced, the valve guides must be serviced and replaced if necessary.


CHUCK-SPINDLE KNOB
CHUCK SPINDLE
SPECIAL-OFFSET-DISH GRINDING WHEEL
VALVE HEAD
HOUSING-FEED-SCREW HANDLE
CHUCK-SPINDLE-HOUSING ANGLE MARK
SLIDE-FEED-SCREW HANDLE

81.9

Figure 3-30.–Valve refacing machine.

Valve Guide Service

Servicing of valve guides is an important, but often neglected, part of a valve job. The guide must be clean and in good condition before a good valve seat can be made. Wear of valve guides is generally the only trouble you will encounter with them.

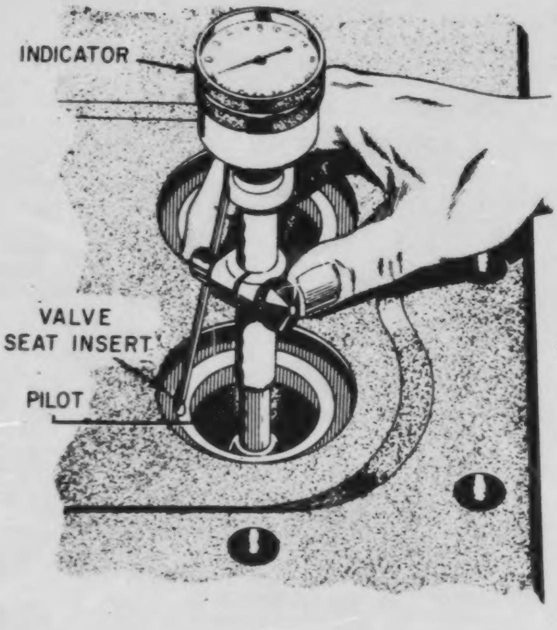
There are several satisfactory methods of checking for valve guide wear. One procedure for flathead guide service includes the use of a dial indicator. With the valve in place, turn the engine so the valve is moved off its seat. Install the dial indicator on the block with indicating button touching the edge of the valve head. Move the valve sideways to determine the amount of wear. Another checking procedure involves the use of a small hole gage to measure the inside of the guide and a micrometer to measure the valve stem; the difference in the readings will be the clearance. Check the manufacturer's manual for the allowable maximum clearance. When the maximum clearance is exceeded, the valve guide will need further servicing before you proceed with the rest of the valve job.

Servicing procedures will depend on whether the guide is of the integral or the replaceable type. If of the integral type, it must be reamed to a larger size and a valve with an oversize stem installed. But if it is of the replaceable type, it should be removed and a new guide installed.

KNURLING of the valve guides has become more popular as a method of compensating for wear of the valve guides. Knurling is accomplished by inserting a special tool in the worn guide attached to an electric drill. This method is not recommended if the guide has been worn excessively or previously knurled.

Valve guides should be removed and replaced with special drivers. When working on a valve-in-head engine, you may use an arbor press to remove and replace valve guides.

After the valve guides are serviced and the valve seats are ground, check the concentricity of the two with a valve seat dial indicator (fig. 3-31). Any irregularity in the seat will register on this dial.



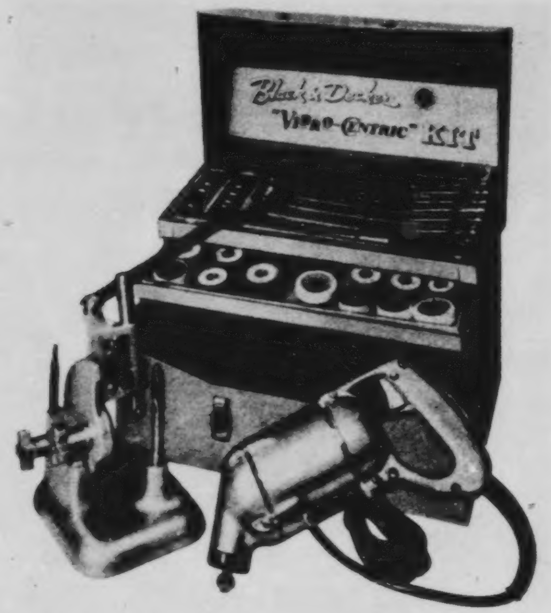
75.73

Figure 3-31.–Using a valve seat dial gage.

Valve Seat Service

If a replaceable seat is badly worn or ground down, replace it with a new one. Remove the old seat either with a puller or by drilling it on two opposite sides and then breaking it in halves with hammer and chisel. New inserts should be chilled in dry ice for about 15 minutes to shrink them so that they can easily be driven into place.

In most cases the valve seats are not replaceable, so they must be ground. Figures 3-32 through 3-34 illustrate the equipment used in valve seat grinding. Be sure you know how to operate the kind of equipment that is in your shop. Study the manufacturer's manual for specific instructions.



2.28X

Figure 3-32.—Valve seat grinding equipment.

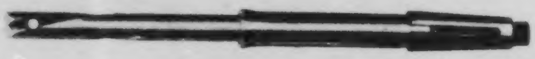

2.29X

Figure 3-33.—Self-centering valve guide pilot.

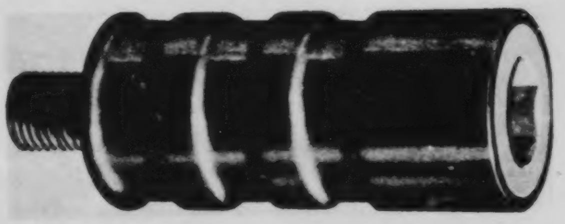

2.30X

Figure 3-34.—Valve seat grinding stone sleeve.

Select the proper size pilot (fig. 3-33) for the valve guide and insert and lock it into the guide. Wipe the valve seat free of carbon dust and oil. Then with a clean oily rag, apply a thin film of oil to the pilot shaft.

Use two or more stone sleeves (fig. 3-34) to facilitate seat grinding if the engine block has both soft and hard seats or if a high-polish finish grind is desired. One sleeve may carry a soft seat stone, another a hard seat stone, and a third sleeve a finishing stone.

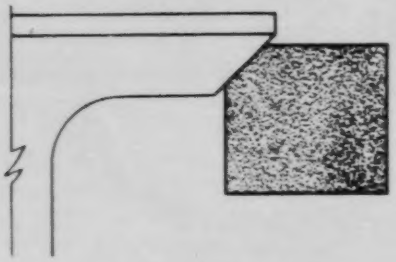
All purpose stones are now available that will do all of the above grinding jobs with one stone. Make sure the stones are dressed at the proper angle in accordance with the engine manufacturer's specifications.

Only a few seconds are required to recondition the average valve seat. Check the progress of the grinding operation often and make sure that you do not remove any more material than is necessary to get a good seat.

Although recommended, it is usually not necessary to lap the contact surfaces of the valve and valve seat after they have been ground. Always check your work by testing one or two of the valves. This check can be made by spreading a thin coat of prussian blue on the valve face or by putting lead pencil marks on the valve seat. If, when turning a valve on its seat, an even deposit of the coloring is seen on the valve seat, or the pencil lines are removed, the seating is perfect. The valve should not be rotated more than 1/8 turn as a high spot could give a false indication if turned one full revolution.

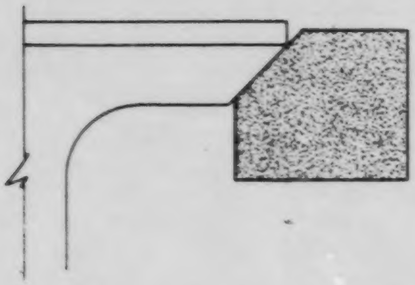
Figure 3-35 shows a normal valve seat which will vary according to the manufacturer's specification. When a great deal of grinding is necessary on a badly burned or worn seat, a condition such as that shown in figure 3-36 will occur. When this happens, you should narrow and center the valve seat by using a 20° stone to cut down the upper portion of the valve seat, and a 70° stone to cut down the lower portion of the seat. Figure 3-37 illustrates a valve seat that has been narrowed down from the top of the valve seat.

Grinding with the narrowing stones usually requires only a few seconds. Check often while grinding so that you will not remove too much metal.



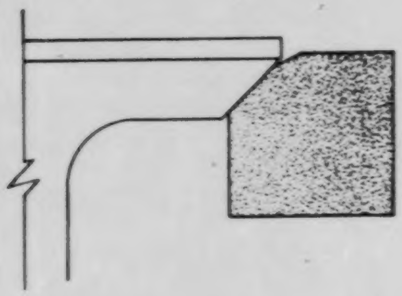
2.32

Figure 3-35.–Normal valve seat.



2.33

Figure 3-36.–Valve seat too wide and low in block.



2.34

Figure 3-37.–Correct valve seat after narrowing seat.

Checking Rocker Arms

After rocker arms have been removed, they should be inspected for wear or damage. Rocker arms with bushings can be rebushed if the old bushing is worn. On some rocker arms, the valve ends, if worn, can be ground down on the valve refacing machine. Excessively worn rocker arms should be discarded.

The silent lash rocker arm can be disassembled by removing the eccentric retaining pin. If more than one rocker arm is being disassembled, do not mix the parts; make sure all parts go back into the rocker arms from which they were taken. When reassembling a rocker arm, make sure the eccentric is installed so that the recessed dot (which is on the side with the smaller radius) is next to the plunger.

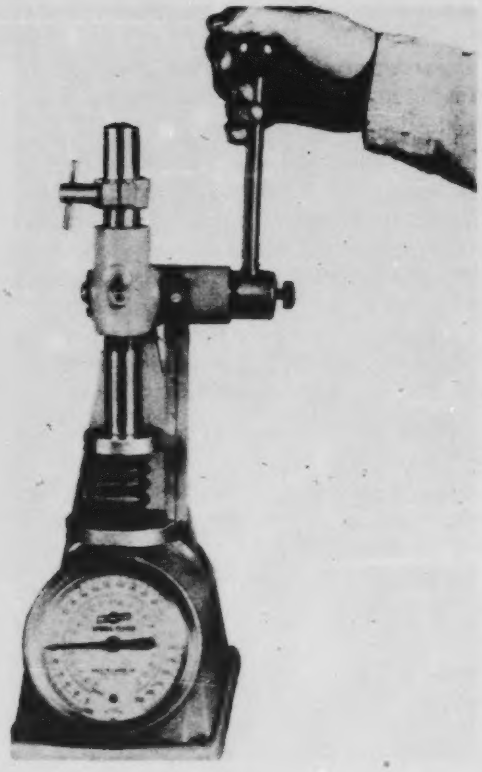
When reinstalling rocker arms and shafts in the cylinder head, make sure that the oilholes (in shafts so equipped) are on the underside so they will feed oil to the rocker arms. Be sure that all springs and rocker arms are restored to their original positions as the shafts are attached to the head.

Checking Valve Springs

While working with valves, you may notice that some of them have more than one spring. These additional springs are coiled to offset a tendency of the valve to vibrate at high engine speeds. They also insure proper valve seating and provide a safety factor in case one spring should break.

Test valve springs for uniformity and strength. For an accurate test use a valve spring tester (fig. 3-38) when one is available. If a valve spring tester is not available, place used springs on a level surface beside a pair of new springs. Use any straightedge to determine irregularities in height. Replace worn out springs with new ones. Unequal or cocked valve springs will offset, in the assembled job, all the precision that has been put into the grinding operation.

When you have reassembled an engine after reconditioning the valves, make sure the adjusting screws are backed off before rotating the engine. A valve that is too tight could strike and damage the piston, or the valve, or both.



2.[illegible]X

Figure 3-38.—Valve spring tester.

Following the recommended procedure, adjust the valves to meet the manufacturer's specification. Never attempt to adjust valves with solid lifters by "ear." If, after adjusting the valves with a gage, there is still excessive valve-lash noise, do not attempt to tighten the adjustment until the noise disappears. To do so may result in severe damage to the engine. When valves are excessively noisy after adjustment, the components of the valve operating mechanisms should be disassembled and inspected for abnormal wear of faulty components.

On any engine on which valve adjustments have been made, be sure that the adjustment locks are tight and that the valve mechanism covers and gaskets are in place and securely fastened to prevent oil leaks.

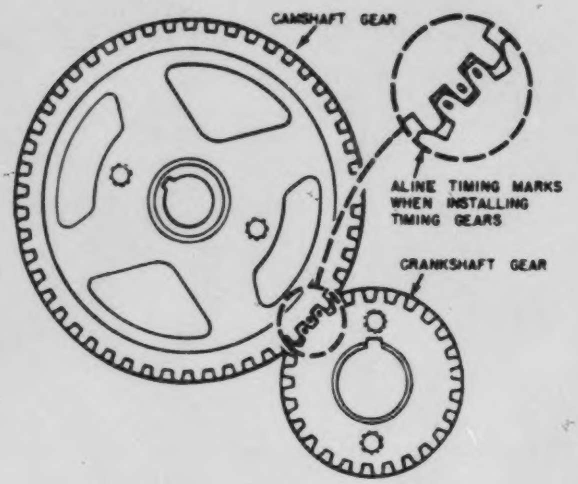
TIMING GEARS (GEAR TRAINS)

Timing gears keep the crankshaft and camshaft turning in proper relation to one another so that the valves open and close at the proper time. In some engines, sprockets and chains are used.

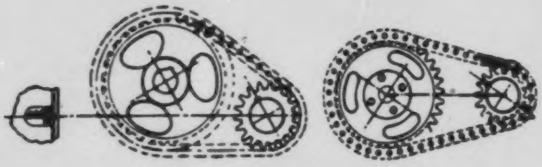
The gears or sprockets, as the case may be, of the camshaft and crankshaft are keyed in position so that they cannot slip. Since they are keyed to their respective shafts, they can be replaced if they become worn or noisy.

With directly driven timing gears (fig. 3-39), one gear usually has a mark on two adjacent teeth and the other a mark on only one tooth. To time the valves properly, it is necessary only to mesh the gears so that the two marked teeth of one gear straddle the single marked tooth of the other.

In the case of chain-driven sprockets the correct timing may be obtained by having a certain number of chain-link teeth between the marks, or by lining up the marks with a straightedge as shown in figure 3-40. In the latter method the position of the piston is determined by markings on the engine flywheel. Some engines have timing marks on the crankshaft fan pulley if no opening is provided in the flywheel housing. Always check the manufacturer's instructions when you are in doubt about the method of timing the engine you are overhauling.



81.69
Figure 3-39.–Timing gears and their markings.



81.70
Figure 3-40.–Methods of valve timing with chain drive.

ENGINE BEARINGS

Bearings are installed in an engine where there is relative motion between parts. Engine bearings are called sleeve bearings because they are in the shape of a sleeve that fits around the rotating journal or shaft. Connecting-rod or crankshaft (also called main) bearings are of the split, or half, type (fig. 3-41). On main bearings, the upper bearing half is installed in the counterbore in the cylinder block. The lower bearing half is held in place by the bearing cap (fig. 3-1). On connecting-rod bearings, the upper bearing half is installed in the rod and the lower half is placed in the rod cap (fig. 3-10). The small-end (or piston-pin) bearing in the connecting rod is of the full-round, or bushing type.

The main bearings in most engines do not have the oil distributing grooves as shown in figure 3-41. They may or may not have the annular grooves; many engines do not. On other engines, only the upper halves of the main bearings have them. On still other engines, both the upper and lower main-bearing halves have the annular grooves. Connecting-rod big-end bearings usually do not have oil grooves.

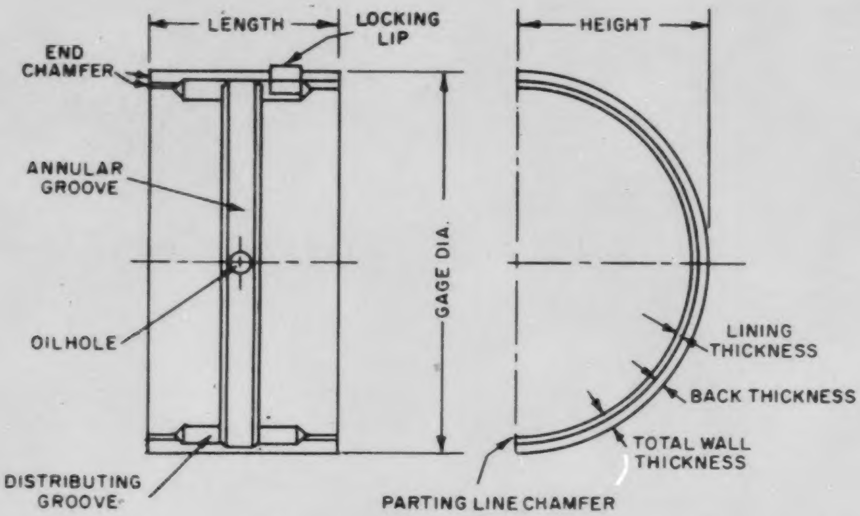
The typical bearing half is made of a steel or bronze back to which a lining of bearing material is applied. (See fig. 3-41.) The bearing material is relatively soft. Thus, if wear takes place, it will be the bearing rather than the more expensive engine part that wears. Then, the bearing rather than the engine part can be replaced when wear has progressed to the replacement point.

Bearing Lubrication

The journal must be smaller in diameter than the bearing (fig. 3-42) so that there will be clearance (called oil clearance) between the two parts; oil circulates through this clearance. The lubricating system constantly feeds oil to the bearing. The oil enters through the oilhole (fig. 3-41) and fills the oil groove in the bearing. From there, the rotating journal carries the oil around to all parts of the bearing. The oil works its way to the outer edges of the bearing. From there, it is thrown off and drops back into the oil pan. The oil thrown off helps lubricate other engine parts, such as the cylinder walls, pistons, and piston rings.

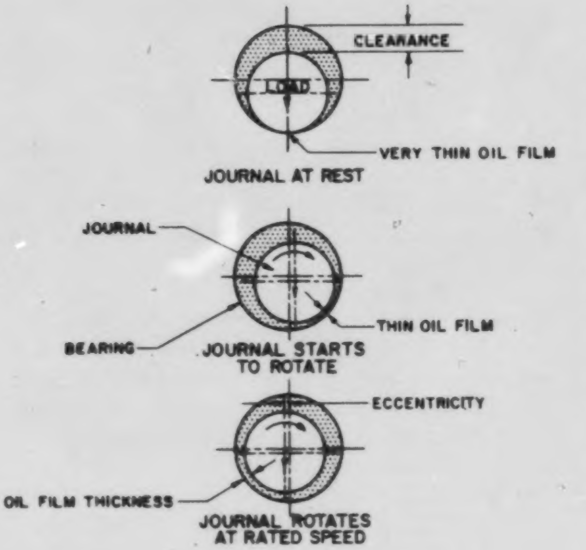
As the oil moves across the faces of the bearings, it not only lubricates them but also helps to cool them. The oil is relatively cool as it leaves the oil pan. It picks up heat in its passage through the bearing. This heat is then carried down to the oil pan and released to the air passing around the oil pan. The oil also flushes and cleans the bearings. It tends to flush out particles of grit and dirt that may have worked into the bearing. The particles are carried back to the oil pan by the circulating oil. They then tend to drop to the bottom of the oil pan or are removed from the oil by the oil screen or filter.

The greater the oil clearance (fig. 3-42), the faster the oil will flow through the bearing.


LENGTH
LOCKING LIP
END CHAMFER
ANNULAR GROOVE
OILHOLE
DISTRIBUTING GROOVE
GAGE DIA.
HEIGHT
LINING THICKNESS
BACK THICKNESS
TOTAL WALL THICKNESS
PARTING LINE CHAMFER

81.337

Figure 3-41.—Typical sleeve-type bearing half.


CLEARANCE
LOAD
VERY THIN OIL FILM
JOURNAL AT REST
JOURNAL
THIN OIL FILM
BEARING
JOURNAL STARTS TO ROTATE
ECCENTRICITY
OIL FILM THICKNESS
JOURNAL ROTATES AT RATED SPEED

81.338

Figure 3-42.—Oil clearance between bearing and shaft.

Thus, as bearings wear, more and more oil is thrown onto the cylinder walls. The piston rings cannot handle an excessive amount of oil; part of it works up into the combustion chambers, where it burns and forms carbon. Resulting carbon accumulation in the combustion chambers reduces engine power and causes other engine troubles. Excessive bearing oil clearances can also cause some bearings to fail from oil starvation. Here's the reason: The oil pump can deliver only so much oil. If the oil clearances are excessive, most of the oil will pass through the nearest bearings. There won't be enough for the more distant bearings; these bearings will probably fail from lack of oil. An engine with excessive bearing oil clearances usually has low oil pressure; the oil pump cannot build up normal pressure because of the excessive oil clearances in the bearings.

On the other hand, if oil clearances are not sufficiently great, there will be metal-to-metal contact between the bearing and shaft journal. Extremely rapid wear and quick failure will result. Also, there will not be enough oil throwoff for adequate lubrication of cylinder walls, pistons, and rings.

Bearing Requirements

Bearings must be able to do other things besides carry the loads imposed on them, as noted below.

1. LOAD-CARRYING CAPACITY. Modern engines are lighter and more powerful. They have higher compression ratios and thus impose greater bearing loads.

2. FATIGUE RESISTANCE. When a piece of metal is repeatedly stressed so that it flexes or bends, it tends to harden and ultimately breaks; this is called FATIGUE FAILURE. Repeatedly bending a piece of wire or sheet metal will demonstrate fatigue failure. Bearings are subjected to varying loads and are thus repeatedly stressed. The bearing material must be able to withstand these varying loads without failing from fatigue.

3. EMBEDABILITY. This term refers to the ability of a bearing to permit foreign particles to embed in it. Dirt and dust particles enter the engine despite the air cleaner and oil filter. Some of them work onto the bearings and are not flushed away by the oil. A bearing protects itself by permitting such articles to sink into, or embed in, the bearing lining material. If the bearing were too hard to allow this, the particles would simply lie on the surface. They would scratch the shaft journal and probably gouge out the bearing. This, in turn, would cause overheating and rapid bearing failure. Thus, the bearing material must be soft enough for adequate embedability.

4. CONFORMABILITY. This is associated with embedability. It refers to the ability of the bearing material to conform to variations in shaft alinement and journal shape. For example, suppose a shaft journal is slightly tapered. The bearing under the large diameter will be more heavily loaded. If the bearing material has high conformability, it will flow slightly away from the heavily loaded areas to the lightly loaded areas. This redistributes the bearing material so that the bearing is more uniformly loaded. A similar action takes place when foreign particles embed in the bearing. As they embed, they displace bearing material, thus producing local high spots (fig. 3-43). However, with high conformability, the material flows away from the high spots. This tends to prevent local heavy loading that could cause bearing failure.

5. CORROSION RESISTANCE. The bearing materials must be resistant to corrosion, since some of the byproducts of combustion may form corrosive substances.

6. WEAR RATE. The bearing material must be sufficiently hard and tough so that it will not wear too fast. At the same time, it must be soft enough to permit good embedability and conformability.

Bearing Materials

The bearing back is usually of steel. The lining material is a combination of several metals, mixed, or alloyed, to provide the combination of desired characteristics. Such metals as copper, lead, tin, mercury, antimony, cadmium, and silver are used. Many combinations are possible. Each ingredient, or metal, supplies certain characteristics. The engine designer selects the combination of ingredients that will best suit the engine.

AUXILIARY ASSEMBLIES

We have discussed the main parts of the engine proper; but there are other parts, both moving and stationary, that are essential to

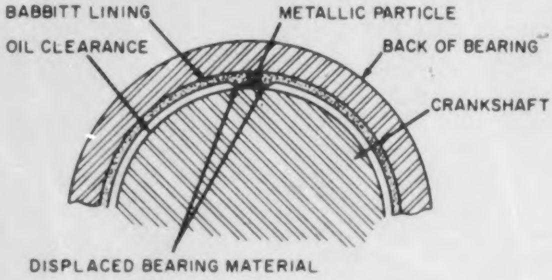


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Figure 3-43.–Effect of a metallic particle embedded in bearing material (Babbit lining).

engine operation. They are not built into the engine itself, but, in most cases, are attached to the engine block or cylinder head.

The fuel system includes a fuel pump and carburetor mounted on the engine. In diesel engines the fuel injection mechanism replaces the carburetor. An electrical system is provided to supply power for starting the engine and also for ignition during operation. An efficient cooling system is necessary for operating an internal combustion engine. In water cooled engines a water pump and fan are used, while in air-cooled engines a blower is generally used to force cool air around the engine cylinders.

POWER PACKAGE CONCEPT

As you were reading the foregoing discussion on engine structure, you may have become aware of the unitary nature of the engine. Its parts are designed so that the whole assembly can be removed from and replaced in the vehicle as a unit or PACKAGE. This is the POWER PACKAGE CONCEPT. If a vehicle requires a major engine job, it is not necessary to tie it up while the work on the engine is being done. Instead, the power plant can be removed and another one quickly installed in the vehicle.

CHAPTER 4

FUEL SYSTEMS

The fuel system of the internal combustion engine is designed to provide the proper quantity of fuel to the engine under all normal operating conditions. The type of fuel used in either a gasoline or a diesel engine varies according to the design of the engine and the geographical location in which the engine will operate. Additionally, each application of the engine may require changes in the type or design of fuel pump, carburetor, or fuel injection components.

Governors are used to control engine speed on stationary as well as on some automotive gasoline engines. All diesel engines used by the Navy have governors to control the engine speed and prevent excessive fluctuation of speed.

This chapter presents information on various types of fuel systems, their components, and how the components function to provide fuel to the engine in the proper quantity.

FUELS

Fuels used in modern Navy equipment are manufactured for use in various geographical locations. For instance, fuels manufactured for use in subzero temperatures must be more volatile than those for use in tropical areas. Otherwise, the fuel in cold climates would not vaporize (evaporate) readily enough to allow efficient engine operation. The result would be hard starting, excessive fuel consumption, and a marked decrease in power developed by the engine. These problems are solved for you by the manufacturer and the supply department. Your concern with the fuel system is in the maintenance and repair of the system's components to insure long life and economical operation of the engine.

Gasoline contains carbon and hydrogen in such proportions that the gasoline burns freely and liberates HEAT ENERGY. If all the potential heat energy contained in a gallon of gasoline could be converted into work, a motor vehicle could run hundreds of miles on each gallon. However, only a small percentage of this heat energy is converted into mechanical energy by the engine. Most authorities consider the power losses within the engine to be as follows:

Engine	Percent of Power Loss
Cooling System	35
Exhaust Gases	35
Engine Friction	5 to 10
Total	75 to 80

The question of what is ideal gasoline is more theoretical than practical. Every manufacturer recommends the octane rating of the gasoline he feels is best for the engines he produces. Besides engine design, factors like the weight of the vehicle, the terrain and highways over which it is to be driven, and the climate and altitude of the locality also determine what gasoline is best to use.

PROPERTIES OF GASOLINE

The function of the gasoline fuel system is to store, transfer and provide gasoline to the

67

engine in varying quantities to insure a proper fuel-air mixture at all engine operating speeds. In order for this system to function properly, it is necessary that the gasoline have the right qualities to burn evenly no matter what the engine's demands are. To help you recognize the qualities required of gasoline used for fuel, let us examine some of the properties of gasoline and their effects on the operation of the engine.

VOLATILITY

The blend of a gasoline determines its VOLATILITY–that is, its tendency to change from a liquid to a vapor at any given temperature. The rate of vaporization increases as the temperature of the gasoline rises.

A gasoline of low volatility brings about better fuel economy and combats VAPOR LOCK (the formation of vapor in the fuel lines in a quantity sufficient to block the flow of gasoline through the system). In the summer and in hot climates, fuels with low volatility lessen the tendency toward vapor lock.

ANTIKNOCK QUALITY AND DETONATION

Reviewing the process of combustion in chapter 2 will help you understand the ANTIKNOCK quality of gasoline. When any substance burns, its molecules and those of the oxygen in the air around it are set into motion, producing heat that unites the two groups of molecules in a rapid chemical reaction. In the combustion chamber of an engine cylinder, the gasoline vapor and oxygen in the air are ignited and burn. They combine, and the molecules begin to move about very rapidly, as the high temperatures of combustion are reached. This rapid movement of molecules provides the push on the piston to force it downward on the power stroke.

In modern high compression gasoline engines the air-fuel mixture tends to ignite spontaneously or to explode instead of burning rather slowly and uniformly. The result is a knock, a ping, or a DETONATION. In detonation the spark from the spark plug starts the fuel mixture burning, and the flame spreads through the layers of the mixture, very quickly compressing and heating them. The last layers become so compressed and heated that they explode violently. The explosive pressure strikes the piston head and the walls of the cylinder, and causes the knock you hear in the engine. It is the fuel, not the engine that knocks. Besides being an annoying sound, persistent knocking results in engine overheating, loss of power, and increased fuel consumption. It causes severe shock to the spark plugs, pistons, connecting rods, and crankshaft. To slow down this burning rate of the fuel, a fuel of a higher octane rating must be used.

OCTANE RATING

The property of a fuel to resist detonation is called its antiknock or OCTANE rating. The octane rating is obtained by comparing the antiknock qualities of gasoline in a special test engine. In the test engine, the compression can be raised or lowered, and other engine controls are provided to make the engine knock or detonate. Two separate fuel chambers are also provided, with a rapid means of changing from the fuel being tested to the standard reference fuel. This reference fuel consists of a mixture of iso-octane, which has a very high antiknock rating, and heptane, which produces a pronounced knock. The octane rating of a gasoline being tested is the percentage by volume of iso-octane that must be mixed with normal heptane in order to match the knocking of the gasoline being tested. Octane numbers range from 50 to over 100. A number higher than 100 indicates that the antiknock value is greater than that of iso-octane.

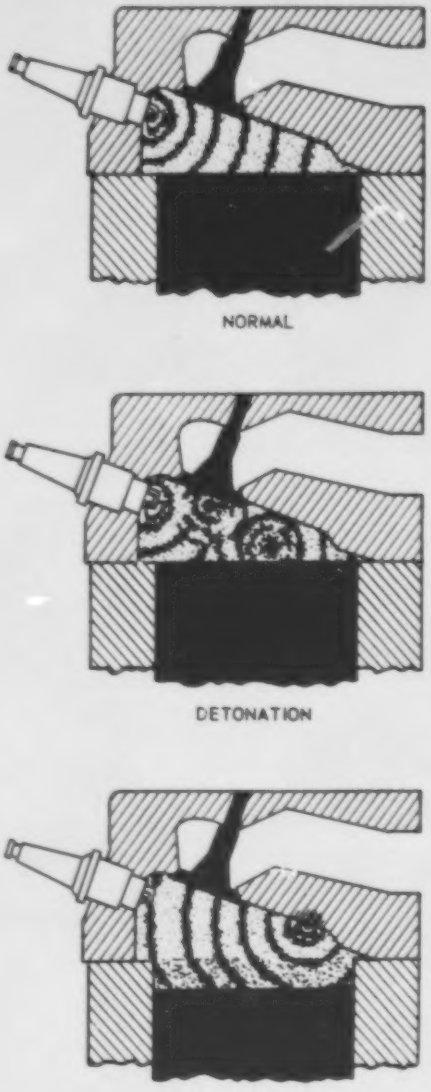
The octane rating of gasoline can be raised in two ways: by mixing it with another fuel, or by treating it with a chemical. While alcohol and benzol can be added to improve the antiknock rating of a gasoline, their use will reduce the heat-producing value of the fuel. In this country, where alcohol and benzol are not commonly used for fuel, a chemical is added to gasoline to improve its octane rating.

The best chemical for this purpose is tetraethyl lead compound, which is added to the gasoline with ETHYL FLUID. In addition to the tetraethyl lead, ethyl fluid contains other chemicals that prevent lead deposits from forming within the engine. Lead oxide causes considerable corrosion.

The LEAD CONTENT of ethyl fluid is very poisonous. Ethyl gasoline should be used only for engine fuel and for no other purpose. It should NEVER be used as a cleaning agent.

An engine which does not knock on a low octane fuel will not operate more efficiently by using a fuel of high octane rating. An engine which knocks on a given fuel should use one of a higher rating. If a higher octane fuel does not stop the knocking, some mechanical adjustments are probably necessary. Retarding the spark so that the engine will fire later may end knocking. However, an engine operating on retarded spark will use more fuel and will overheat. It may be less expensive to use a higher priced, high-octane gasoline with an advanced spark than to use a cheaper, low-octane gasoline with a retarded spark.

Besides a spark which is too advanced, a lean fuel mixture, a defective cooling system, or preignition also may be responsible for knocking. Preignition should not be confused with engine knock itself, which occurs late in the combustion process, after the spark has occurred. In preignition the air-fuel mixture begins to burn before the spark occurs. This condition may be caused by an overheated exhaust valve head, hot spark plugs, or glowing pieces of carbon within the combustion chamber. In figure 4-1 you see the diagrammed course of the air-fuel mixture in the cylinder under circumstances of preignition and detonation, as well as in normal combustion.


NORMAL

DETONATION

PREIGNITION

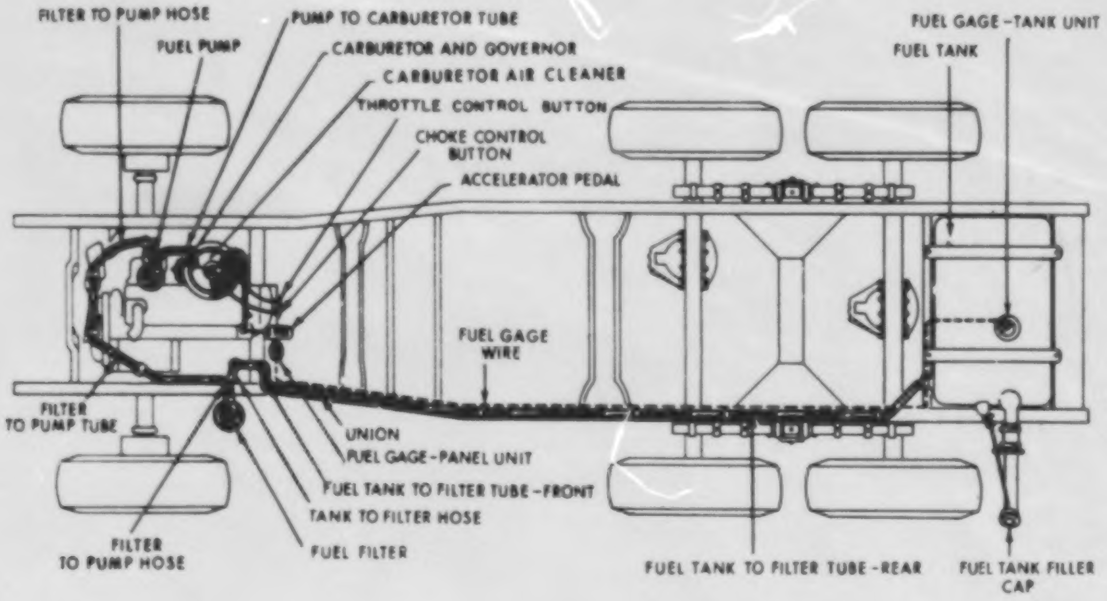
81.72

Figure 4-1.—Combustion process.

GASOLINE FUEL SYSTEM COMPONENTS

The gasoline fuel system (fig. 4-2) consists of the fuel tank, fuel pump, fuel filter, carburetor intake manifold, and fuel lines or tubes, connecting the tank, pump, and carburetor.

The fuel system supplies a combustible mixture of gasoline and air to the engine cylinders. It stores the gasoline in liquid form in a fuel tank, then converts this liquid into a vapor and mixes it with air. The mixture enters the engine cylinders on the intake strokes; it is then compressed and ignited. In burning, the fuel-air mixture expands and high pressure is therefore produced in the engine cylinders. This pressure


FILTER TO PUMP HOSE
FUEL PUMP
PUMP TO CARBURETOR TUBE
CARBURETOR AND GOVERNOR
CARBURETOR AIR CLEANER
THROTTLE CONTROL BUTTON
CHOKE CONTROL BUTTON
ACCELERATOR PEDAL
FUEL GAGE-TANK UNIT
FUEL TANK
FUEL GAGE WIRE
FILTER TO PUMP TUBE
UNION
FUEL GAGE-PANEL UNIT
FUEL TANK TO FILTER TUBE-FRONT
TANK TO FILTER HOSE
FILTER TO PUMP HOSE
FUEL FILTER
FUEL TANK TO FILTER TUBE-REAR
FUEL TANK FILLER CAP

81.75

Figure 4-2.—Typical fuel system for a gasoline engine.

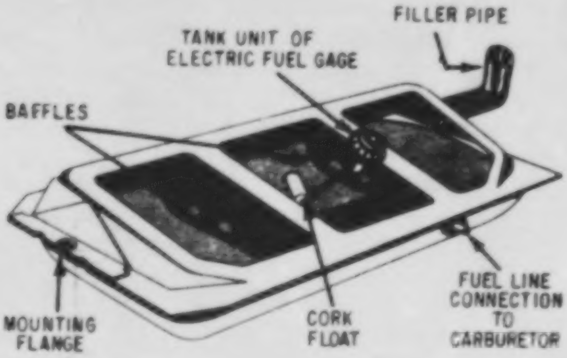
forces the pistons downward on the power strokes. The fuel system must vary the proportions of air and gasoline for different operating conditions. For normal running with a warm engine, the proper mixture ratio is about 15 pounds of air to 1 pound of gasoline. But for initial starting with a cold engine, a much richer mixture is needed; the mixture does not burn as readily in a cold engine and the gasoline does not turn to vapor so readily. Also, when accelerating, or during high-speed or full-load operation, a richer mixture is required. RICHNESS here means a higher proportion of gasoline; a mixture of 9 pounds of air to 1 pound of gasoline would be a rich mixture. The opposite of RICHNESS is LEANESS. A 15 to 1 mixture ratio would be a relatively lean mixture.

Some gasoline engines use a fuel-injection system. With this system, a pump delivers fuel to a fuel injector. The injector then injects the proper amount of fuel into the cylinder head, near the intake valve, during the intake stroke.

FUEL TANK

On passenger vehicles the fuel tank is generally mounted in the rear of the chassis. On trucks, it is generally installed under or behind the driver's seat or on the frame behind or to the side of the cab.

Figure 4-3 illustrates the general construction of a fuel tank used on automotive equipment. Most fuel tanks are of similar construction. They are usually made of rust resistant sheet metal, and have an inlet or filler pipe and an outlet. The outlet, with a fitting for the fuel-line connection, may be in the top or side of the tank. The lower end of the outlet pipe is placed about one-half inch from the bottom of the tank so that any sediment which collects in the tank will not be carried to the carburetor. Baffle plates may be placed inside the tank to reinforce the sides and bottom and to prevent the fuel from surging or splashing. A drain plug is placed in the bottom so that the tank can be drained and cleaned. The fuel tank


FILLER PIPE
TANK UNIT OF ELECTRIC FUEL GAGE
BAFFLES
FUEL LINE CONNECTION TO CARBURETOR
MOUNTING FLANGE
CORK FLOAT

81.76
Figure 4-3.–Fuel tank with top cut away.

must be equipped with an air vent. This vent is usually located in the cap of the inlet pipe.

Some vehicles, especially heavy-duty ones, have more than one tank. On these the auxiliary tanks are interconnected, and each has a shutoff valve, so that the flow of fuel from one or more of the tanks may be turned off.

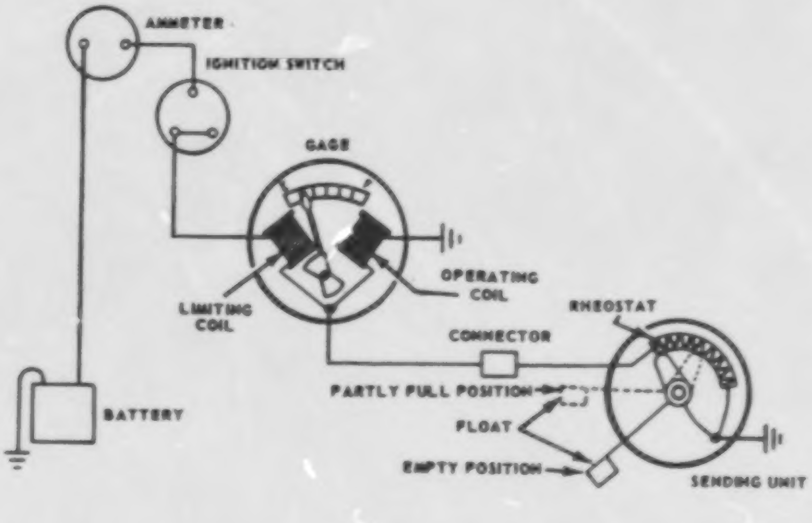
Fuel tanks give little or no trouble, and as a rule require no servicing other than an occasional draining and cleaning. However, if they are punctured or develop leaks, they should not be welded or repaired with or near an open flame until all traces of fuel and fuel vapors have been completely removed from the tank. Before attempting to make any repairs to a fuel tank, always consult with the shop supervisor for specific instructions on all safety precautions to be observed. Remember that fuel tanks can be extremely dangerous.

Fuel Gages

The fuel gage is a signaling system which indicates the amount of fuel in the tank. Most fuel gages are electrically operated and are composed of two units: the gage itself, which is mounted on the instrument panel of the vehicle; and the sending unit, which is mounted on the fuel tank.

An electrical fuel gage normally operates only when the ignition switch is turned on.

The tank unit of the BALANCING COIL-TYPE FUEL GAGE (fig. 4-4) has a float and arm assembly connected to a sliding contact. As the fuel level in the tank changes, the position of the contact changes on a rheostat winding, thus varying circuit resistance and


AMMETER
IGNITION SWITCH
GAGE
OPERATING COIL
LIMITING COIL
RHEOSTAT
CONNECTOR
PARTLY FULL POSITION
FLOAT
EMPTY POSITION
BATTERY
SENDING UNIT

81.77
Figure 4-4.–Coil-type gage circuit.

resulting current flow. The unit on the instrument panel contains two magnetic coils (limiting coil and operating coil) and a permanent magnet which is attached to the gage needle. When the fuel tank is empty, the limiting coil is stronger than the operating coil, thus the magnet is drawn toward it and the needle reads EMPTY on the gage. As the tank is filled, the operating coil becomes stronger, attracting the magnet and moving the needle toward the F or FULL position.

Fuel Tank Caps

The fuel tank cap is designed to seal the filler tube of the fuel tank and prevent the fuel from escaping on hills and inclines. The cap allows air to enter the tank as the fuel is used, or seals the opening to the tank when other means of ventilation are used to vent the tank. Valves are incorporated in fuel tank caps used on tactical vehicles if the vehicle's fuel tank will be under water for fording purposes. Using the wrong type of cap can restrict the pumping action of the fuel pump or may cause the fuel tank to collapse.

FUEL FILTER

In figure 4-5, a common type of filter is shown attached to the fuel pump. The fuel enters a bowl and passes up through the filter screen, then out through the outlet. Any water or solid matter caught by the filter falls to the bottom of the filter bowl. Dirt in fuel generally comes from rust scales in tank cars, storage tanks, and drums. Water caught by the filter generally comes from condensation of moisture in the fuel tank or is introduced through delivery from storage facilities. The filter element is usually a fine metal-mesh screen. Thumbscrews or spring wire clips hold the sediment bulb in place against a cork washer.

Another type of filter is made of a series of laminated disks placed within a large bowl which acts as a settling chamber for the fuel and encloses the disks or strainer assembly (fig. 4-6). Some vehicles use inline filters with either paper or ceramic elements. These are replaced when the flow of fuel is restricted.

FUEL PUMP

The fuel pump must deliver enough fuel to supply the requirements of the engine, and also

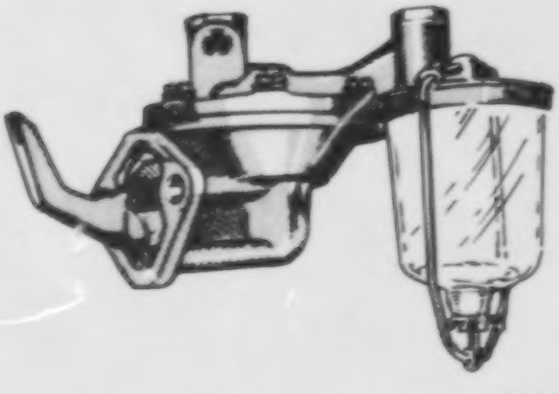


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Figure 4-5.—Fuel pump with attached filter bowl.

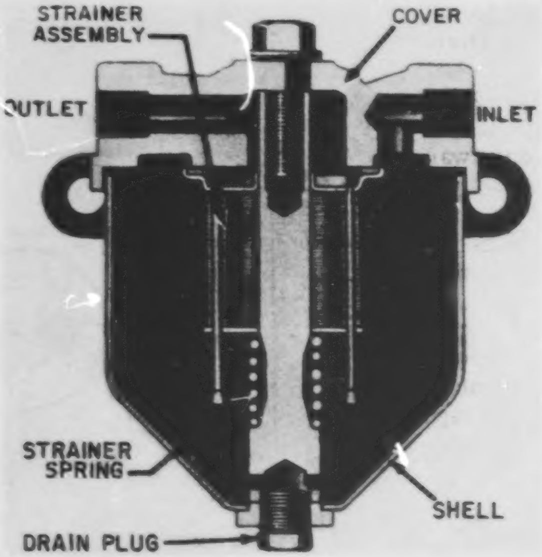

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Figure 4-6.—Fuel filter.

maintain a proper pressure in the line between the fuel pump and the carburetor.

Excessive fuel-pump pressure holds the carburetor float needle off its seat, causing a high-gasoline level in the float chamber, which in turn increases gasoline consumption. Too low a fuel-pump pressure may cause an insufficient fuel flow into the carburetor and cause air locks (vapor locks) to occur in the fuel lines. Air in the fuel line will interrupt the flow of fuel to the carburetor resulting in engine power loss or operational failure. The average fuel pump operating pressure will vary from 3 to 5 psi. The pump should be tested periodically to insure proper operating pressure.

The vacuum gage is normally used to check the output of the fuel pump. To check the output, remove the fuel line, leading from the pump to the carburetor, from the fuel pump. Attach the vacuum gage to the fuel line connection with the use of an adapter supplied with the gage. While cranking the engine, observe the reading on the pressure scale. If no vacuum gage is available, any liquid pressure gage, designed for use with petroleum products, with a small scale reading, can be used. If pressure is not within the manufacturer's specifications, the pump should be removed and rebuilt or replaced.

During the suction stroke of a mechanical fuel pump, the rotation of an eccentric on the camshaft moves the pump operating arm which pulls the diaphragm lever and the diaphragm downward. This downward motion against the pressure of the diaphragm spring produces a vacuum in the pump chamber. The vacuum holds the outlet valve closed, atmospheric pressure pushes the inlet valve open, and fuel is delivered from the supply tank. The fuel flows through the inlet, up through the filter screen, and down through the inlet valve into the pump chamber. During the return stroke, the diaphragm is forced up by the diaphragm spring, the inlet valve closes, and the outlet valve is forced open. This action allows the fuel to flow through the outlet to the carburetor.

The diaphragm operating lever is hinged to the pump arm at the arm pivot so that it can be moved down but cannot be raised by the pump arm. The pump arm spring makes that arm follow the cam without moving the lever. The lever is moved upward only by the diaphragm spring. The pump, therefore, delivers fuel to the carburetor only when the fuel pressure in the outlet is less than the pressure maintained by the diaphragm spring. This condition arises when the fuel passage from the pump into the carburetor float chamber is open and the float needle valve is not seated. The carburetor float and needle valve control the fuel level in the carburetor. The dome-shaped air chamber found on some fuel pumps is added to smooth out the pulsation (surging) of fuel being pumped.

Fuel pumps are classified as positive and nonpositive diaphragm. The POSITIVE type continues to pump fuel even when the carburetor bowl is filled and requires a method of bypassing the fuel back to the tank. The NONPOSITIVE DIAPHRAGM PUMP is the one usually found in the gasoline engine. It delivers fuel to the carburetor only when it is needed for the requirements of the engine. The diaphragm is a reciprocating disk that causes the pumping action.

Some pumps, especially on truck and bus engines, operate electrically. One type of electric pump uses a motor to drive a set of gears, impeller, or centrifugal rotor (fig. 4-7), and is

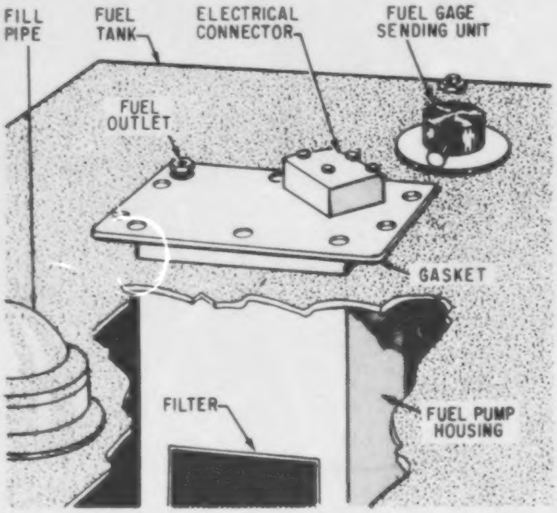

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Figure 4-7.–Tank unit type electric pump.

installed directly in the tank compartment. The inlet of the pump is submerged in the fuel. This application is a positive displacement pump and return lines are necessary to bring excess fuel back to the tank.

A bellows autopulse type pump (fig. 4-8) is used quite extensively in military equipment. It is in operation at all times when the ignition switch is on. An electric circuit expands the bellows through a solenoid switch to take in a charge of fuel. The expanded bellows breaks the circuit through contact points and the collapsing action of the bellows forces the fuel through the lines when the carburetor requires it to maintain the float level.

Repair kits are provided for overhauling either type of fuel pump. The diaphragm, composed of several layers of specially treated cloth which is not affected by gasoline, will wear and need replacing. A good indication of a diaphragm leaking is the presence of gasoline in the crankcase. Current models of diaphragm pumps leak externally when failure occurs, thus preventing dilution of their oil. Excessive wear in the operating linkages will prevent proper pumping action. New diaphragms, washers, springs, check valves, and other necessary replacement parts will be found in the repair kit of this particular type of pump. There is also a kit for repairing the bellows type of pump.

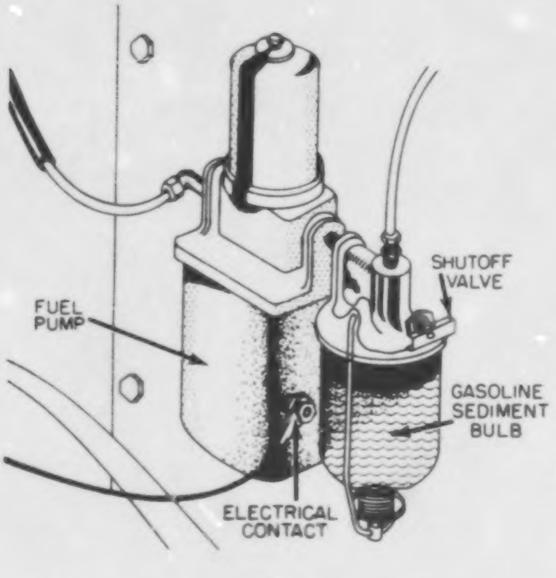

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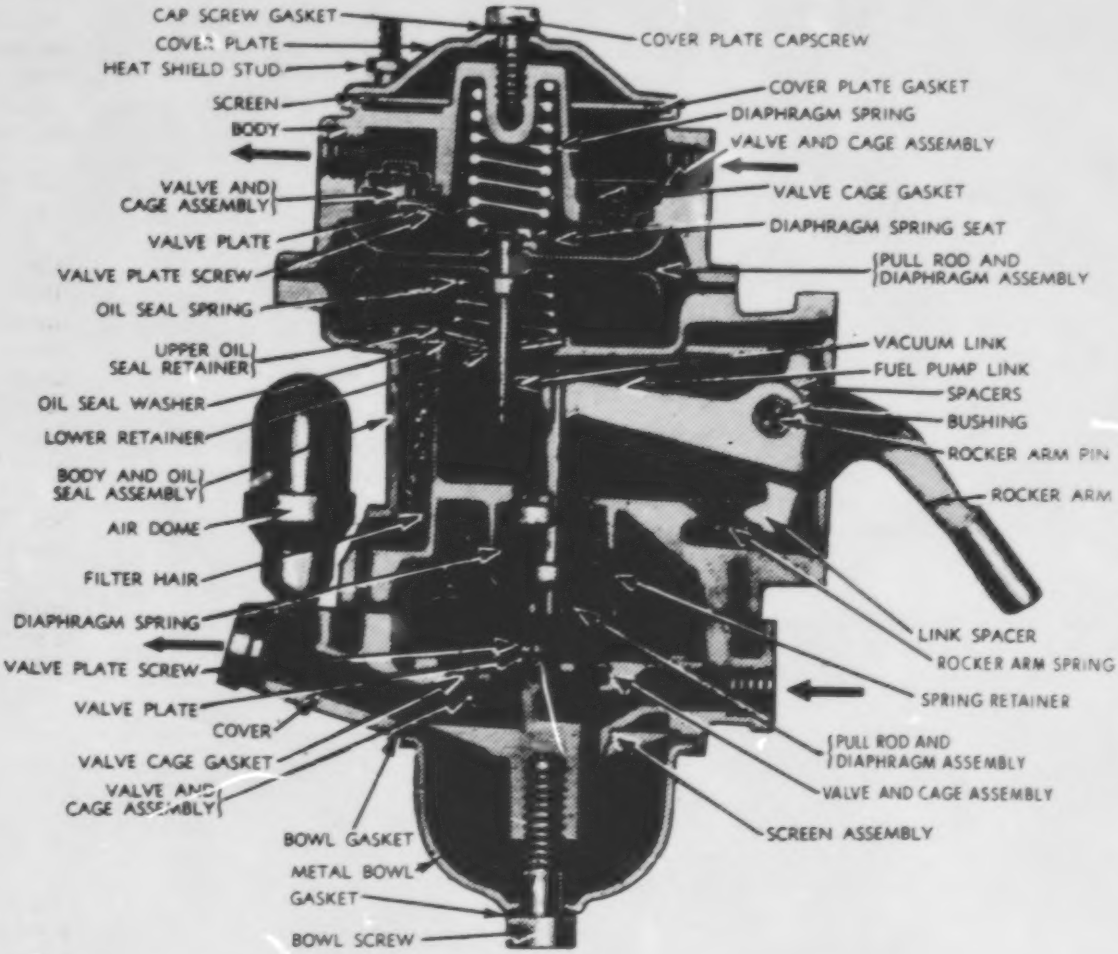
Figure 4-8.—Autopulse type electric pump.

Some pumps have vacuum boosters (fig. 4-9) built into them to provide for positive operation of the vacuum type windshield wiper at all times. These boosters overcome any failure of the wipers on acceleration and on full throttle. They operate the wipers only when the manifold vacuum itself is not sufficient to maintain action. The booster unit diaphragm is pushed up when the rotation of the camshaft eccentric moves the rocker arm and expels air through the exhaust valve. On the return stroke of the rocker arm, a spring moves the diaphragm down, creating a vacuum in the pump chamber. This vacuum keeps the windshield wipers operating normally when the throttle is wide open. When the wipers are not being used, the vacuum holds the diaphragm up against spring pressure so that it is not fully pushed up at each rocker arm movement.

FUEL LINES

FUEL LINES connecting the various units of the fuel system are usually made of copper tubing. However, copper tubing is being replaced by steel tubing which is rustproofed by copper or zinc plating. You have learned about cutting and fitting tubing in *Tools and Their Uses*, NAVPERS 10085-B. Three kinds of fittings are shown in figure 4-10. There are the flared, compression, and soldered types. Of the three, the flared fitting is most common.

Fuel lines are placed away from exhaust pipes, mufflers and manifolds so that excessive heat will not cause vapor locks. They are attached to the frame, engine, and other units so that the effects of vibration will be minimized. Fuel lines should be free of contact with sharp edges which might cause wear. In places of excessive movement, as between a vehicle frame and rubber-mounted engine, short lengths of gasoline-resistant flexible tubing are used. Occasionally, road vibration may loosen and


CAP SCREW GASKET
COVER PLATE
HEAT SHIELD STUD
SCREEN
BODY
VALVE AND CAGE ASSEMBLY
VALVE PLATE
VALVE PLATE SCREW
OIL SEAL SPRING
UPPER OIL SEAL RETAINER
OIL SEAL WASHER
LOWER RETAINER
BODY AND OIL SEAL ASSEMBLY
AIR DOME
FILTER HAIR
DIAPHRAGM SPRING
VALVE PLATE SCREW
VALVE PLATE
COVER
VALVE CAGE GASKET
VALVE AND CAGE ASSEMBLY
BOWL GASKET
METAL BOWL
GASKET
BOWL SCREW
COVER PLATE CAPSCREW
COVER PLATE GASKET
DIAPHRAGM SPRING
VALVE AND CAGE ASSEMBLY
VALVE CAGE GASKET
DIAPHRAGM SPRING SEAT
PULL ROD AND DIAPHRAGM ASSEMBLY
VACUUM LINK
FUEL PUMP LINK
SPACERS
BUSHING
ROCKER ARM PIN
ROCKER ARM
LINK SPACER
ROCKER ARM SPRING
SPRING RETAINER
PULL ROD AND DIAPHRAGM ASSEMBLY
VALVE AND CAGE ASSEMBLY
SCREEN ASSEMBLY

81.81

Figure 4-9.—Fuel pump with vacuum booster.

break the lines, or they could become pinched or flattened by flying rocks. Such damage could interfere with the flow of the fuel.

A certain amount of scale forms within the lines and sometimes causes a stoppage. If this condition occurs, blow the lines clear with compressed air.

CARBURETOR

The principles of carburetion are presented so you may better understand the inner workings of a carburetor and how the other components of the fuel system function to provide a combustible mixture of fuel and air to the engine cylinders.

Air is composed of various gases, mostly nitrogen and oxygen. These gases are, in turn, made up of tiny particles called molecules. All substances, whether solid, liquid, or gas, are made up of molecules. In solids, such as ice or iron, the particles are held very closely together so that they seem to have no motion. In liquids, the molecules are not held together so tightly, so

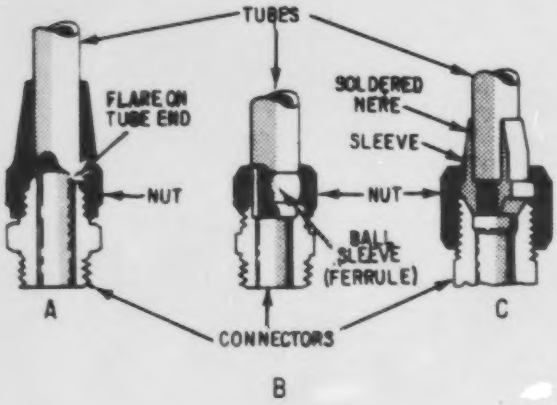


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Figure 4-10.—Types of fittings used on fuel lines. (A) Flared. (B) Compression. (C) Soldered.

they can move with respect to each other. In gases, there is still less tendency for the molecules to hold together and the molecules can therefore move quite freely. The molecules of a gas are attracted to the earth by gravity, or by their weight. It is the combined weight of the countless molecules in the air that make up atmospheric pressure.

When a liquid changes to a vapor, it has evaporated. When this happens, molecules of the liquid move from the liquid into the air. As this continues, the liquid disappears from its container and appears as vapor in the air. The rapidity of evaporation varies with a number of factors. One of these is the volatility of the liquid. Others include temperature, total pressure above the liquid, and amount of liquid, and amount of liquid that has already evaporated into the air above the liquid.

When a substance is heated the molecules move faster. This is true regardless of whether the molecules are in a solid, liquid, or gas. In other words the rate of evaporation increases with increased temperature. This action can be seen in the process of boiling water.

When there is little gas (atmospheric) pressure above the liquid, the molecules can escape from the liquid more easily than when the pressure is high. This is to say that liquid in a partial vacuum will evaporate more rapidly than the same liquid under pressure.

If the evaporation is taking place in a closed chamber, as for instance in a jar, evaporation of the liquid will soon stop; the closed space above the liquid will soon become "filled" with escaped molecules. These escaped molecules are in motion, just as all other molecules are moving. Some of the escaped molecules will be knocked back into the liquid. This action balances the escapes so that for every molecule that leaves the liquid, a molecule will reenter the liquid. As a result, state of balance exists and evaporation can be said to have stopped.

VOLATILITY refers to the ease with which a liquid vaporizes. A highly volatile liquid evaporates very rapidly. A liquid of low volatility evaporates slowly. Gasoline is a mixture of several different components with varying degrees of volatility.

ATOMIZATION means breaking a liquid into very tiny particles or globules. Atomization helps to turn a liquid into a vapor. If a spoonful of gasoline is put into a pan, it will take several seconds for it to evaporate, the length of time depending on temperature, volatility, and pressure. However, if this spoonful of gasoline is put into an ordinary spray gun (fig. 4-11), the gasoline will be broken into a fine mist when operating the gun and this mist will turn almost instantly into vapor. The reason for this is that a much greater area of the liquid is exposed to air when the gasoline is atomized. Evaporation takes place from all surfaces and increases with greater surface area.

A venturi is an hourglass-shaped restriction. In the carburetor (fig. 4-12), a venturi is placed in the air horn through which the air must pass on its way to the intake manifold and the engine

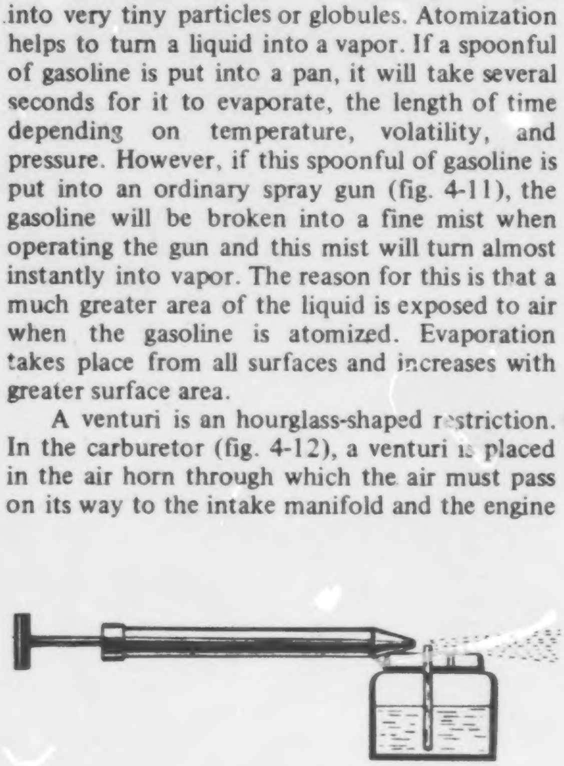

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Figure 4-11.—Spray gun.

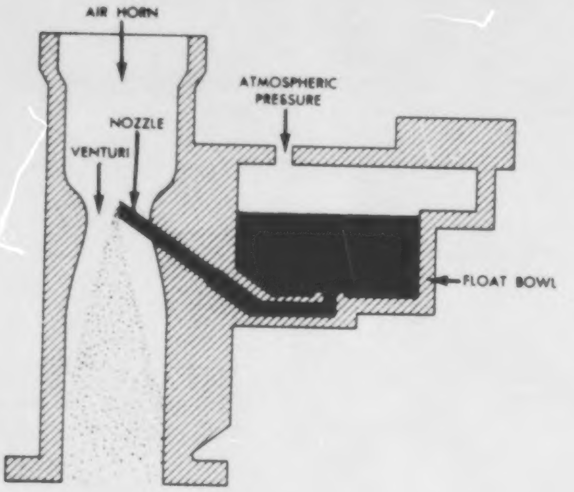

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Figure 4-12.–Simplified carburetor.

cylinders. The purpose of the venturi is to create a partial vacuum (pressure less than atmospheric) at the outlet of the nozzle. This will permit the atmospheric pressure on the surface of the gasoline in the float bowl to force the gasoline out through the nozzle. This gasoline then sprays and atomizes in the passing air to form the fuel-air mixture.

Several controls and circuits must be added to the simplified carburetor shown in figure 4-12 for it to vary the fuel-air ratio for different operating conditions. These controls and circuits include the accelerating system, which momentarily enriches the mixture for improved acceleration when the throttle is opened; the maximum power circuit, which enriches the mixture when the throttle is opened wide for high-speed or full-speed operation; the float system, for keeping a constant level of gasoline in the carburetor bowl; the idling circuit, for supplying an enriched mixture during engine idling; and the choke circuit for engine starting.

Throttle

The throttle is a device in the carburetor that is used to vary the amount of fuel-air mixture that enters the intake manifold. This is necessary so the speed of the engine can be controlled. The throttle valve (fig. 4-13) is simply a round disk mounted on a shaft so it can be tilted at various angles in the carburetor throttle valve body. When it is parallel to the air flow, it offers almost no restriction and a full volume of fuel-air mixture can pass into the intake manifold. The throttle valve is connected by linkage to the control (accelerator pedal and hand throttle) in the driver's compartment.

Float Circuit

The float circuit maintains the fuel level in the carburetor bowl at a constant level during engine operation. (See fig. 4-14.) The float circuit automatically permits fuel to flow into the bowl when the fuel level drops below a predetermined level, and shuts off the supply of fuel when the level reaches the specified height. Up-and-down movement of the float on the fuel controls the fuel supply by means of a needle valve and seat.

The float level must be set with accuracy in accordance with the manufacturer's

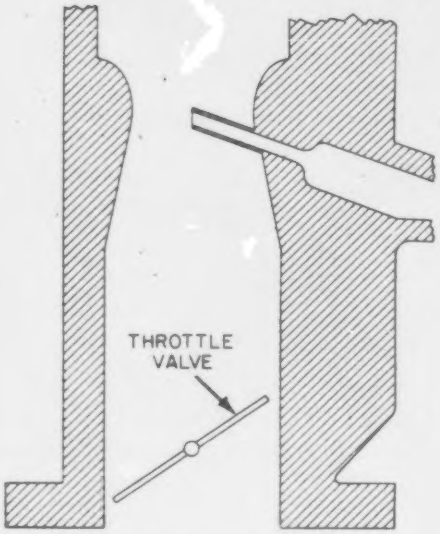

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Figure 4-13.–Simple carburetor with throttle valve.

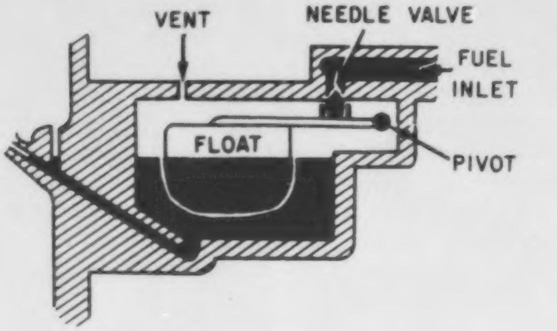

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Figure 4-14.—A typical float circuit.

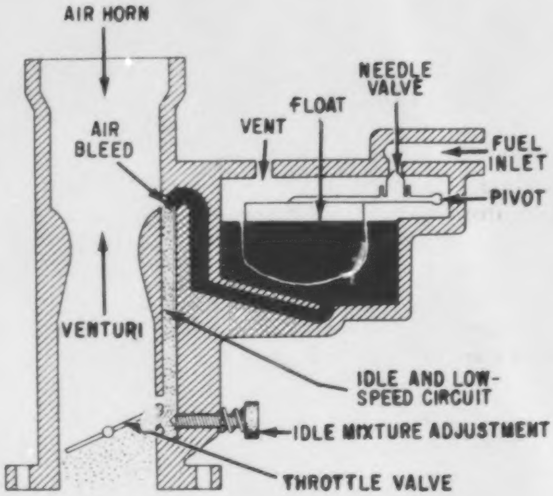

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Figure 4-15.—A simplified idle- and low-speed circuit.

specifications. If the fuel level is too low, insufficient fuel will be supplied to the jets, and engine performance will be sacrificed. On the other hand, if the fuel level is too high, excessive fuel will reach the jets. In fact, fuel may continue to flow from the jets when the engine is stopped. In actual operation, the float and needle valve maintain a position that permits the fuel coming in to just balance the fuel that is flowing to the jets.

Low-Speed Circuit

When the throttle is almost closed, there will be very little air passing through the venturi. Therefore, there will be very little vacuum at the venturi and the fuel nozzle will not discharge any appreciable amount of fuel. Without some additional circuit to assure fuel delivery with a closed throttle, the engine would stop. The circuit that takes care of fuel delivery during closed or nearly closed throttle is called the IDLE- AND LOW-SPEED CIRCUIT (fig. 4-15). Actually, in some respects, this is really two circuits: an idle circuit and a low-speed circuit.

When the throttle is closed, there is a relatively high vacuum in the intake manifold and below the throttle. The idle circuit has a discharge port, or hole, that is just below the throttle valve when it is closed. With a closed throttle, there is a vacuum in the intake manifold and, therefore, at the discharge hole. Atmospheric pressure in the float bowl will force fuel from the float bowl through the idle circuit and out the discharge hole. An adjustable needle valve is arranged to permit more or less fuel to discharge from the hole; this makes it possible to adjust the idling mixture richness by allowing more or less fuel to discharge during idle.

An air bleed is arranged to allow air to bleed into the idle circuit when it is operating. This air mixes with the fuel and partly atomizes it before it discharges from the hole into the air horn. Some such assistance is needed because air movement through the horn is much slower and, therefore, there is less tendency for atomization to take place at the hole during idle. The air bleed also helps to produce fuel flow when pressure differences (between upper and lower portion of the air horn) are low; the mixture flows more easily than liquid fuel alone.

When the throttle is opened a little, the air flow is still too restricted for the venturi to discharge fuel. Yet more air is flowing and, consequently, more fuel must discharge. The idle-circuit discharge hole alone cannot supply this additional fuel. To supply the additional fuel needed for this low-speed operation, an additional hole (low-speed discharge hole or port) is included in the idle circuit. This hole is so placed that it is slightly above the edge of the throttle valve when it is closed, but slightly below the edge of the throttle valve when it is opened a small amount. In this latter position, intake manifold vacuum can act on the low-speed hole and therefore supply additional fuel from the bowl through the circuit. The same circuit is used by both the idle- and the low-speed holes. The low-speed hole simply permits more fuel to discharge into the throttle-valve body as the throttle is swung away from the fully closed position.

High-Speed Circuit

The high-speed circuit consists essentially of the main nozzle, which is centered in the venturi. The carburetor normally contains a multiple venturi; that is, several venturi, one inside another. When the throttle is opened sufficiently, the air passing through creates a pressure difference which causes a discharge of fuel from the nozzle. Throughout the intermediate- and high-speed range, this discharge increases with the volume of air passing through so that a fairly uniform fuel-air mixture ratio is maintained. Assisting in maintaining this fairly constant ratio is an air bleed which is incorporated in the nozzle. With increased air speed through the venturi, increased air bleeding into the main nozzle takes place, preventing overrichness. Note the air bleeds in figures 4-16 and 4-17.

The high-speed and low-speed circuits overlap. As the throttle is moved from closed to opened position, for example, the idle low-speed and high-speed circuits successively take over the main job of supplying fuel. With a closed throttle, the idle discharge hole alone supplies fuel. As the throttle is opened so its edge moves past the low-speed hole, the low-speed hole begins to discharge fuel to meet the added fuel requirements of the engine as engine speed

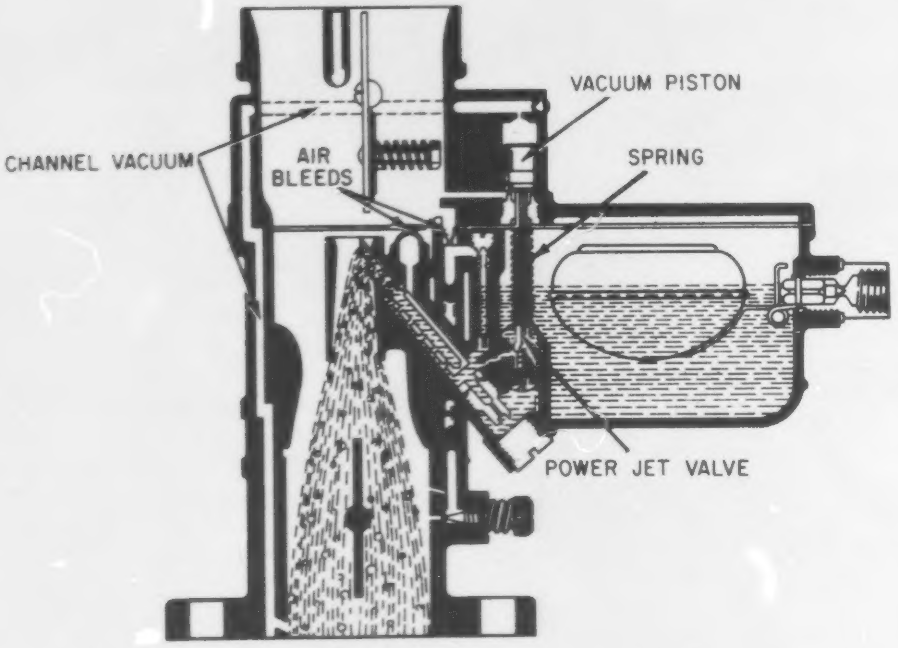

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Figure 4-16.—Power jet full load circuit.

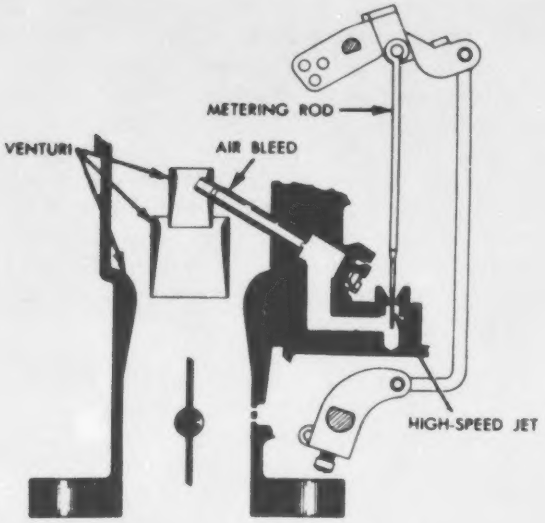

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Figure 4-17.—Metering rod full load circuit.

increases. As the throttle opens still wider, the additional and faster moving air through the air horn begins to produce fuel discharge from the main nozzle. As the main nozzle takes over, the low-speed discharge hole no longer functions.

The carburetor is so designed that the fuel-air ratio of the mixture supplied with an open throttle provides economical operation. This ratio is somewhere around 15:1, by weight.

If the mixture is enriched to around 11:1 or 12:1, the engine will produce greater power even though it will not run quite as economically. To increase engine power for high-speed or heavy-load operation (as when pulling up a hill), and still maintain reasonable economy, an additional circuit is included in the carburetor which enriches the mixture with a wide-open throttle. These are known as the full-load, high-speed circuits and may be of several types.

In some carburetors, a POWER JET provides the additional fuel necessary for maximum power at wide-open throttle. The power-jet valve (fig. 4-16), controlled by a vacuum-actuated piston assembly, operates in accordance with the throttle opening. With the throttle closed, a high manifold vacuum is present, and the vacuum-controlled piston assembly is moved by atmospheric pressure in the float chamber to the top of its cylinder against the tension of a spring, closing the valve. When the throttle is opened to a point where additional fuel is required, the manifold vacuum has decreased sufficiently so that the spring on the piston assembly moves the piston down, thereby opening the power jet to feed additional fuel into the high-speed circuit. The jet valve is sometimes referred to as the economizer valve since its operation provides full-power operation where needed and more economical operation at other times.

Instead of using a power jet, some carburetors accomplish the same result by employing a METERING ROD which varies the size of the high-speed jet openings. Fuel from the float bowl is metered to the high-speed circuit through the calibrated orifice provided by the high-speed jet and the metering rod within it. From this point, the fuel is conducted to the nozzle extending into the venturi. As the throttle valve is opened, its linkage raises the metering rod in the jet. The rod has several steps, or tapers, machined on the lower end and, as it is raised in the jet, it makes the effective size of the fuel orifice greater, permitting more fuel to flow through the circuit to meet the load demand imposed upon the engine. At the wide-open throttle position, the smallest step of the metering rod is in the circular opening of the jet, permitting the maximum amount of fuel to flow through the circuit to meet the requirements of maximum power. The metering rod position must be synchronized with every throttle valve position so that the proper ratio of air and gasoline is delivered to the engine for all speeds and driving conditions.

The VACUUM STEP-UP (fig. 4-18) operates much like the power jet. It consists of a step-up piston which is fastened to a step-up rod. When high vacuum develops in the intake manifold, as it does under part-throttle operation, atmospheric pressure holds the step-up piston down against its spring pressure so that the step-up rod is held down in the step-up jet, thus closing off the jet. With wide-open throttle, there will be a low vacuum in the intake manifold and the

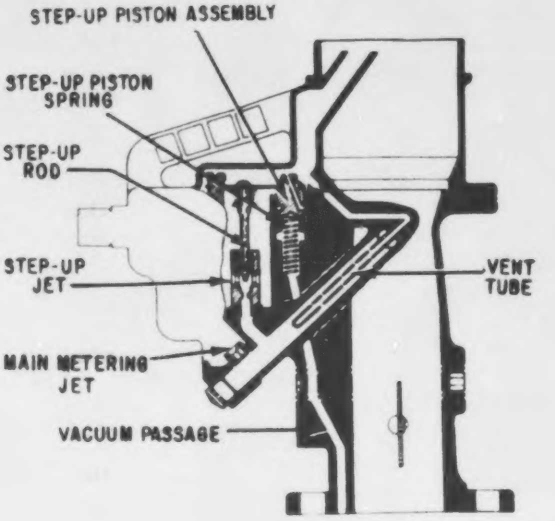

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Figure 4-18.–Vacuum step-up high speed circuit.

difference in pressure above and below the piston is small. Consequently, the piston is moved up by its spring pressure and the rod is raised out of the jet. Additional fuel for full-power operation is supplied.

Accelerating Pump Circuit

The accelerating pump circuit controls a small amount of fuel that is momentarily discharged into the air stream when the throttle is opened quickly. This extra amount of fuel is necessary to insure instantaneous response from the engine on acceleration. When the throttle is suddenly opened, air rushes through both the carburetor and the intake manifold. The air is lighter than the liquid fuel and gets into motion quicker, so it reaches the manifold before the fuel charge supplied by the high-speed system. This results in a momentarily lean mixture and hesitation during fast acceleration. To counteract this condition, additional fuel must be supplied; this is accomplished by the accelerating pump circuit.

The accelerating pump circuit consists of a pump cylinder; a plunger mechanically actuated by a lever mounted on the throttle shaft, or vacuum-operated by intake manifold vacuum; an intake check valve located in the bottom of the pump cylinder to control the passage of fuel from the bowl into the pump cylinder; a discharge check valve; and an accelerating jet to meter the amount of fuel used. A typical arrangement with a mechanically actuated plunger is shown in figure 4-19.

When the throttle is opened, the pump plunger moves downward in its cylinder. If the plunger is mechanically operated, the downward movement will be brought about by direct linkage with the throttle. If it is vacuum-actuated, a sudden throttle opening will cause the manifold vacuum to drop, allowing the accelerating pump spring to force the pump plunger down in the cylinder. In either case, the subsequent action of the accelerating-pump circuit is the same. The downward travel of the plunger forces fuel past the discharge check valve to the accelerating jet, which meters the rate at which it is discharged into the air stream.

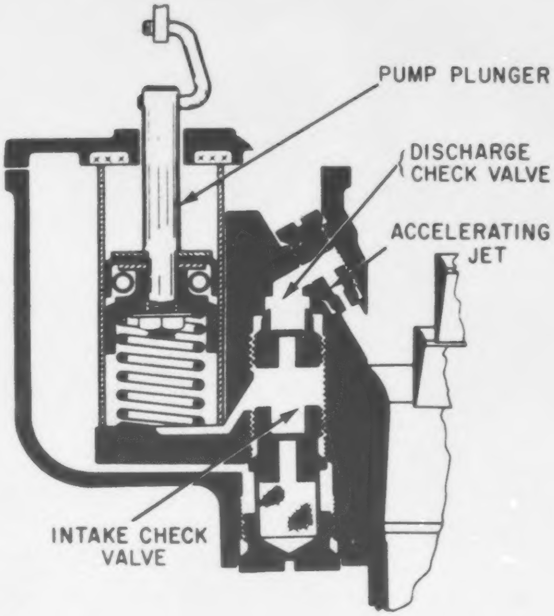

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Figure 4-19.–Carburetor accelerator pump circuit.

Fuel is supplied to the pump cylinder through the intake check valve at the bottom. The level of fuel in the pump cylinder when the plunger is held up to the top of its stroke is approximately equal to the level in the fuel bowl. The intake check valve in the bottom of the cylinder permits a supply fuel to reach the cylinder but closes on the downstroke of the plunger, preventing the fuel in the cylinder from being pushed back into the bowl. The accelerating-pump discharge is needed only momentarily when the throttle is opened suddenly. To prevent the accelerating jet from flowing at constant throttle openings, some models have an air-vent check valve placed between the accelerating jet and pump cylinder above the fuel level. At steady part-throttle positions, when the pump plunger is inoperative, no pressure exists on the fuel in the pump cylinder. Under this condition, the air-vent check valve will be open and the air will enter the passage connecting the pump cylinder and accelerating jet, preventing fuel from flowing through the jet. The pressure on the fuel, created by the downstroke of the pump plunger, causes the air-vent check valve to close against its seat to prevent the fuel from being discharged back into the bowl through the air-vent passage. On some carburetors, the area above the plunger is connected to the intake manifold so that the accelerating pump does not work while the engine is not running. Under these conditions, the pressure in the intake manifold is near atmospheric and holds the pump plunger down.

Sucessful operation of the accelerating pump depends on a delayed action, which provides a continual stream of fuel from the pump jet after the throttle has ceased moving. This is to take care of the fuel demands of the engine in the interval that exists between the time the throttle is opened and the time the high-speed nozzle begins to discharge fuel.

Choke Circuit

When the engine is cold, the gasoline vapors tend to condense into large drops on their way to the cylinders. Because all the gasoline supplied to the cylinders will not vaporize, it becomes necessary to supply a richer mixture to have enough vapor to assure combustion. This is accomplished by the choke circuit, which is a choke valve plate placed in the carburetor throat above the venturi.

When a driver operates the choke, the choke valve tilts in the air horn to reduce the amount of air entering the throat, giving a very rich mixture. Only the volatile parts of the gasoline will vaporize at cold temperatures; therefore, a rich mixture is necessary. It provides enough ignitible vapor to start the engine. However, if the choke valve is in the full-choke position, it is completely closed, shutting off the supply of air. Consequently, there is not enough air entering the throat to allow the gasoline to ignite. The necessary air is admitted in manual chokes by either one of two semiautomatic features.

In one design, the choke valve incorporates a spring-loaded poppet valve (fig. 4-20). The poppet is held in the closed position by a weak

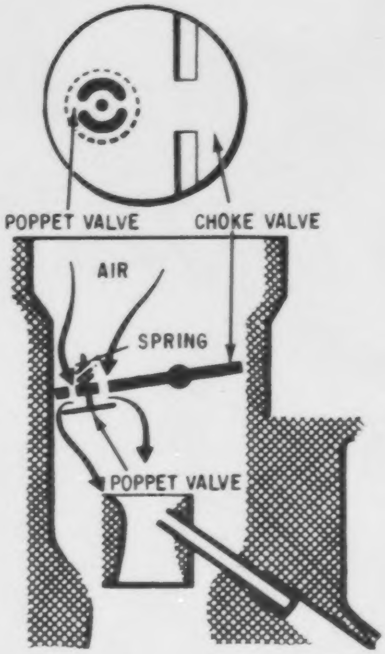

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Figure 4-20.—Spring-loaded poppet valve in choke valve.

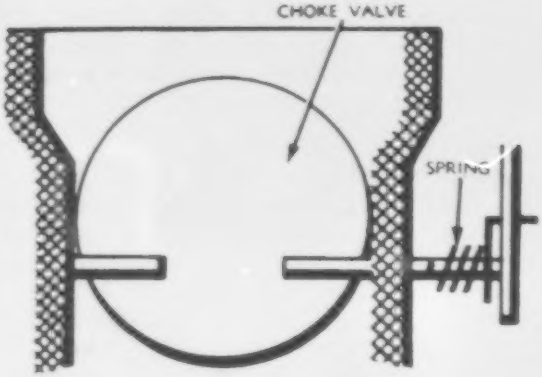

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Figure 4-21.—Offcenter choke valve.

spring. As soon as the engine turns over, there is sufficient pressure differential to open the valve, allowing a small amount of air to flow.

In the other design, the valve is offcenter (fig. 4-21) and operated through a coiled spring on the end of the choke shaft. In the full-choke position, the spring holds the choke valve in the closed position. As soon as the engine turns over, an increased pressure differential overcomes the spring tension and opens the choke valve part way, admitting enough air to prevent overchoking or flooding the engine. As the engine warms up, the choke valve is gradually advanced to the wide-open position by the operator to supply the leaner mixture required for a hot engine.

AUTOMATIC CHOKES (figs. 4-22 and 23) have replaced the conventional manual choke. They control the fuel-air ratio for quick starting at low temperature and also provide for the proper amount of choking to enrich the fuel-air mixture for all conditions of engine operation during the warmup period. The automatic choke built into the carburetor in figure 4-22 consists of a thermostatic (bimetal) spring and a vacuum piston which opposes the action of the spring. The spring is connected to the choke valve in such a manner as to close the valve when the spring is cold. The vacuum piston tends to open the choke valve when the engine manifold vacuum is high. The choke valve is mounted offcenter on the choke shaft so that

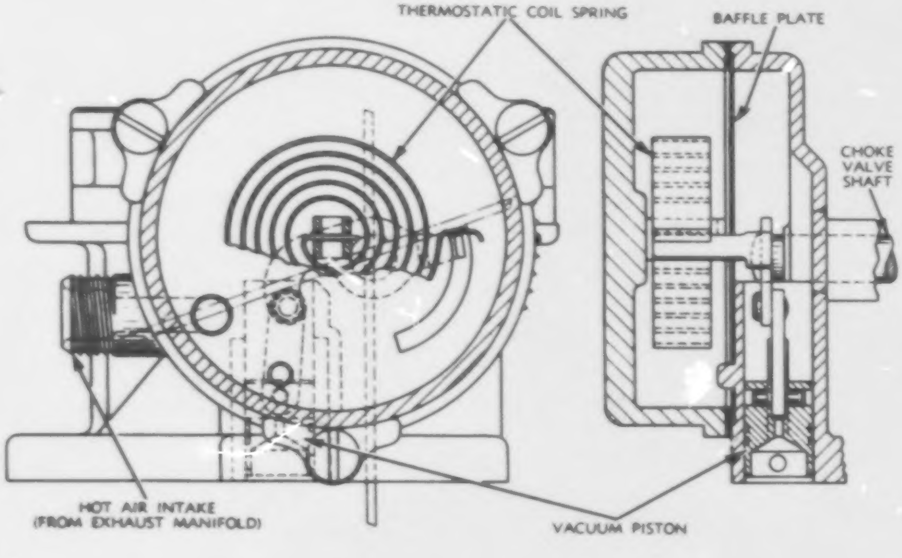

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Figure 4-22.—Automatic choke.

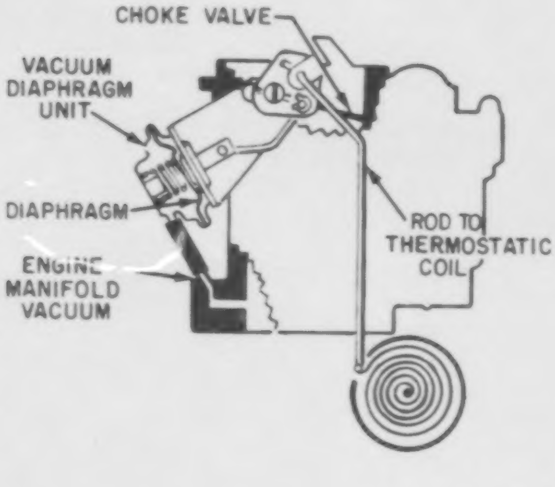

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Figure 4-23.—Automatic choke with thermostatic coil mounted in the manifold.

any increase in air velocity through the air horn will tend to open the valve.

The operation of the automatic choke is dependent on three factors; heat, intake manifold vacuum, and the velocity of air passing through the air horn. When the engine is cold, the thermostatic spring holds the choke valve closed. When the engine is started, the low pressure (high vacuum) below the throttle valve permits atmospheric pressure to move the piston down and partially open the valve against the tension of the thermostatic spring. Under varying load conditions during warmup, the position of the choke valve will be changed by the operation of the vacuum piston working against the thermostatic spring, and the air velocity in the air horn. Hot air from the exhaust manifold is directed to the thermostatic spring so that the spring loses its tension as the engine is heated. This permits the choke to open gradually and, after it reaches full-open position, it is held open by the action of the intake manifold on the piston. When the engine is stopped, the thermostatic spring cools and closes the choke valve. This choke is adjusted by loosening the screws holding the cover of the thermostatic coil, turning the cover either right or left, and retightening the screws. One trouble encountered with this choke is that carbon from the exhaust causes the vacuum piston to stick; as a result, no choking occurs when the engine is cold.

In figure 4-24, the thermostatic coil is mounted in the manifold and connected to the choke valve by mechanical linkage. A vacuum diaphragm is mounted on the carburetor and attached to the linkage to retard choking action after the engine is started. In the operation of the automatic choke illustrated in figure 4-23, the thermostatic coil closes the choke valve until the engine is started. After starting, the vacuum diaphragm, in conjunction with the air entering the carburetor throat, overcomes part of the tension acting on the choke valve from the thermostatic coil, and lessens the choking effect. As the engine warms up, the thermostatic coil continues to expand and open the choke until operating temperature of the engine is reached. This type of choke can be adjusted by two methods. Some manufacturers allow for adjustment by providing more than one attaching point of the linkage to the thermostatic coil, while others provide adjustment by bending the mechanical linkage between the thermostatic coil and the choke shaft. Be sure to check the manufacturer's recommended method before adjusting this type of choke.

Carburetor Troubles

Here are some of the engine troubles that usually (but NOT always) can be traced to some fault in the carburetor system:

1. EXCESSIVE FUEL CONSUMPTION can result from a high float level, a leaky float, a sticking metering rod or full power piston, sticking accelerator pump, and too rich an idling mixture.

2. A SLUGGISH ENGINE may be the result of a poorly operating accelerator pump, sticking high-speed piston, low float level, dirty or gummy fuel passages, or a clogged air cleaner.

3. POOR IDLING, often characterized by a stalling of the engine, usually is due to a too-rich

idle mixture, a defective choke, or an incorrectly adjusted idle speed screw at the throttle valve.

4. FAILURE OF THE ENGINE TO START may be caused by an incorrectly adjusted choke, clogged fuel lines, or air leak into the intake manifold.

5. HARD STARTING OF A WARM ENGINE could be due to a defective or improperly adjusted throttle link.

6. SLOW ENGINE WARMUP may indicate a defective choke or defective radiator thermostat.

7. A SMOKY, BLACK EXHAUST indicates a very rich air-fuel mixture.

8. STALLING OF THE ENGINE AS IT WARMS could be caused by a defective choke or closed choke valve.

9. A BACKFIRING ENGINE may be due to an incorrect, often lean, air-fuel mixture reaching the engine. In turn, this condition could be caused by clogged fuel lines or a fluctuating fuel level.

The more stubborn troubles in a carburetor can sometimes be eliminated only with its disassembly and overhauling. The procedures vary according to the manufacturer's specifications, which you should follow closely.

AIR CLEANER

The air cleaner is placed at the air entrance of the carburetor to remove dust and other foreign matter from the air before it enters the carburetor. A great deal of air, as much as 100,000 cubic feet for every 1000 car miles, is introduced into the engine. Without an air cleaner, dust and grit would enter the engine with the air and would cause excessive wear and operating troubles.

Two types of air cleaner are used: a wet type and a dry type.

The WET-TYPE AIR CLEANER (fig. 4-24) is an oil-bath cleaner, consisting of a main body and a cover. Within this unit are a reservoir of oil and a filter element made of metal gauze or fine metal wool. Air entering the cleaner passes through the opening at the top of the body. The air flows past the oil-filled reservoir, picking up particles of oil and carrying them into the filter. The filter traps the oil and particles and allows the oil to seep back to the reservoir. The air finally hits the cover plate and is deflected down through a passage to the carburetor.

The metal gauze or threads in the filter also act as a flame arrester in case of severe flashback or backfire. Many air cleaners are equipped with a silencing unit called the SOUND NEUTRALIZING CHAMBER. It consists of air-intake passages designed to muffle air noises, and a felt pad that acts as a gasket and absorbs engine intake noises.

The DRY-TYPE AIR CLEANER (fig. 4-25) uses a treated and pleated paper cleaner element which requires periodic replacement. The element is sealed in the air breather by pressure against the rubberized material bonded to the filter element and the cover plate and housing. This type of air cleaner element is gradually replacing the oil-bath type due to its ability to remove smaller particles from the airflow into the engine.

A clogged air cleaner produces an action similar to choking which results in too rich a fuel mixture. Foreign matter passed into the engine because of a poor cleaner will also cause excessive engine wear and operating troubles.

At each chassis lubrication, remove the air cleaner and wash metallic filter elements in nonflammable cleaning solvent. Never wash them in gasoline, for gasoline could be ignited by static electricity, or even by the friction of rubbing surfaces. Paper elements should be replaced at intervals recommended by the manufacturer. Wash the other air cleaner parts. In wet-type cleaners, drain the old oil and add new oil. Be sure that the weight of the new oil conforms to the manufacturer's specifications, and that you add it to the level indicated on the filter body.

AIR INDUCTION AND EXHAUST SYSTEMS

In chapter 2 you learned that intake and exhaust are two of the four basic engine strokes. The intake stroke admits an air-fuel mixture into

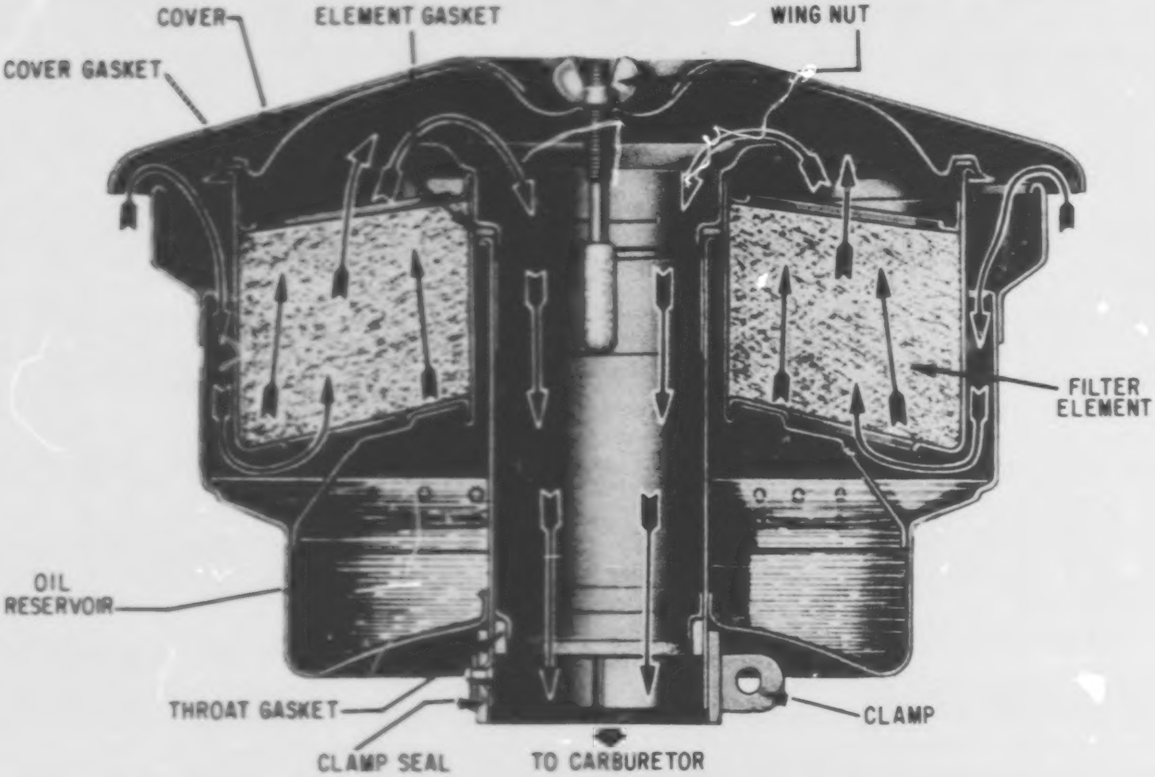
COVER
ELEMENT GASKET
WING NUT
COVER GASKET
FILTER ELEMENT
OIL RESERVOIR
THROAT GASKET
CLAMP
CLAMP SEAL
TO CARBURETOR

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Figure 4-24.—Wet-type air cleaner.

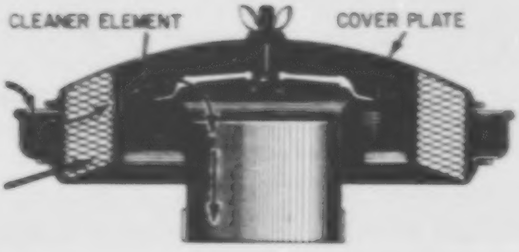
CLEANER ELEMENT
COVER PLATE

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Figure 4-25.—Dry-type air cleaner.

the cylinder, and the exhaust stroke expels the used gases from the engine cylinder. In this section, you will be concerned with the **INTAKE MANIFOLD** and the **EXHAUST MANIFOLD**, the passageways through which the mixtures are admitted and the gases expelled.

The intake manifold is usually a cast iron passage through which the air-fuel mixture passes to each cylinder. The intake manifold should be as short and as straight as possible to reduce chances of condensation and aid the flow of the mixture from the carburetor. The manifold is mounted on the side of the cylinder block in L-head engines, on the side of the cylinder head in I-head engines, and between the two cylinder banks in V-head engines. The intake manifold is fastened by capscrews or held in place by studs extending from the cylinder block, and is secured by a nut and special washer on each stud. The mounting flange for the carburetor is centrally located on the intake manifold so that a uniform mixture can reach the individual cylinders. Connections between the engine block and the manifold, and between the carburetor and the manifold, must be airtight. They are usually sealed by thick gaskets which allow for any slight irregularity in the joining metal surfaces. Leaks and cracks permit air to enter the engine without passing through the carburetor, resulting in a lean and possibly dirty mixture (air containing dust and foreign particles).

The exhaust manifold is usually a cast-iron passage through which the used gases are carried away from the engine cylinders. It is attached to the side of the cylinder block on L-head engines and to the side of the cylinder head on overhead valve engines. On V-8 engines there are two exhaust manifolds, one for each bank of cylinders. The manifolds are usually connected by a crossover pipe and exhaust through a common muffler and tail pipe. Some vehicles with dual exhausts have two mufflers and two tail pipes which increase the efficiency of the engine by reducing back pressure.

The gasket between the exhaust manifold and the cylinder block or cylinder head must withstand the intense heat of the exhaust gases. Although gaskets are made of metal-covered asbestos, they can burn, and they will have to be replaced if the connections become loose. Exhaust gas leaks can be detected by smoke discolorations at the connections. If the leak is bad enough, it can be felt and heard when the engine is running.

A device called a MANIFOLD HEAT CONTROL VALVE is often built into the exhaust manifold to promote better vaporization of the fuel during engine warmup. In cold weather, evaporation of the gasoline in the air-fuel mixture entering the engine is poor, since gasoline evaporates more slowly when it is cold. To assist in the vaporization of the fuel, the heat control valve deflects the exhaust gases toward the intake manifold (shown in fig. 4-26), when the engine temperature is low. As the hot exhaust gases pass around the intake manifold, they heat the manifold and the incoming air-fuel mixture.

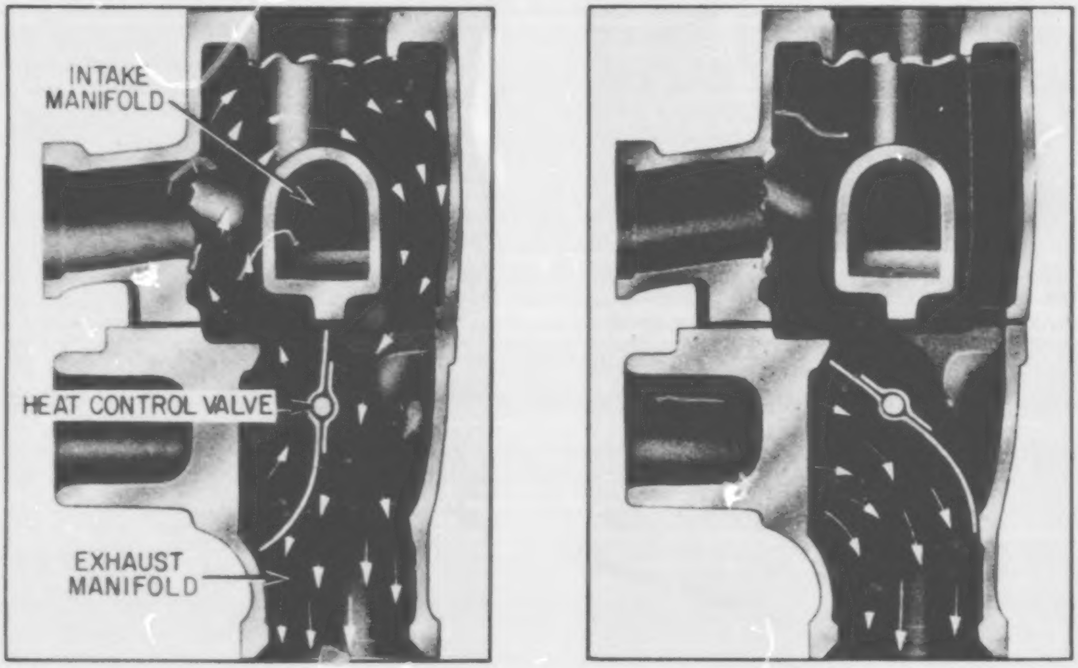

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Figure 4-26.—Flow of exhaust gases around intake manifold.

When the engine is warmed up enough to insure adequate vaporization of the fuel, the valve turns as shown in figure 4-26. Now the used gases are deflected downward into the exhaust pipe and no longer circulate around the intake manifold. The space around the intake manifold which is heated by exhaust gases is sometimes called the HOTSPOT.

This valve should be checked regularly to make sure it operates freely. If the valve sticks in the warmup position, the exhaust valves will burn due to the increased temperature resulting from the restricted flow of exhaust gases.

If you find a stuck valve, add a few drops of penetrating oil mixed with graphite to the shaft and manually work the valve until it becomes free to operate by spring tension.

Before reaching the tail pipe, the used gases pass down the exhaust pipe through the MUFFLER (fig. 4-27). The muffler, exhaust pipe, and tail pipe comprise the exhaust system.

The muffler quiets the noise of the exhaust by reducing the pressure of the used gases. These gases expand and cool in the separate chambers of the muffler. Flames and sparks leaving the exhaust manifold with the gases are "trapped" by the muffler, which also acts as a flame arrester.

The muffler is connected between the exhaust pipe and the tail pipe by slip joints and clamps and is supported from the frame of the vehicle by straps. Rust on the outside of the muffler is caused by snow, rain, and humidity. Rust on the inside results from burning fuel. You have learned that the products of combustion contain water in suspension. This water, trapped in the muffler, will gradually rust it. With every gallon of gasoline that is burned, approximately 6.9 lb of water are formed, and pass through the muffler. Much of this moisture will remain in the muffler if the vehicle is driven only short distances, but most of it will be expelled if the vehicle is driven speedily for a long distance. In time, the rust, together with the pressure of the exhaust gases, will force holes in the muffler, through which the poisonous fumes of carbon monoxide will seep into the vehicle and can affect the occupants, sometimes fatally.

When you install a muffler, be sure that the small drain hole in the case is at the bottom, and that the clamp fasteners are tight.

Mufflers must be replaced immediately if they are known to be defective. They should be

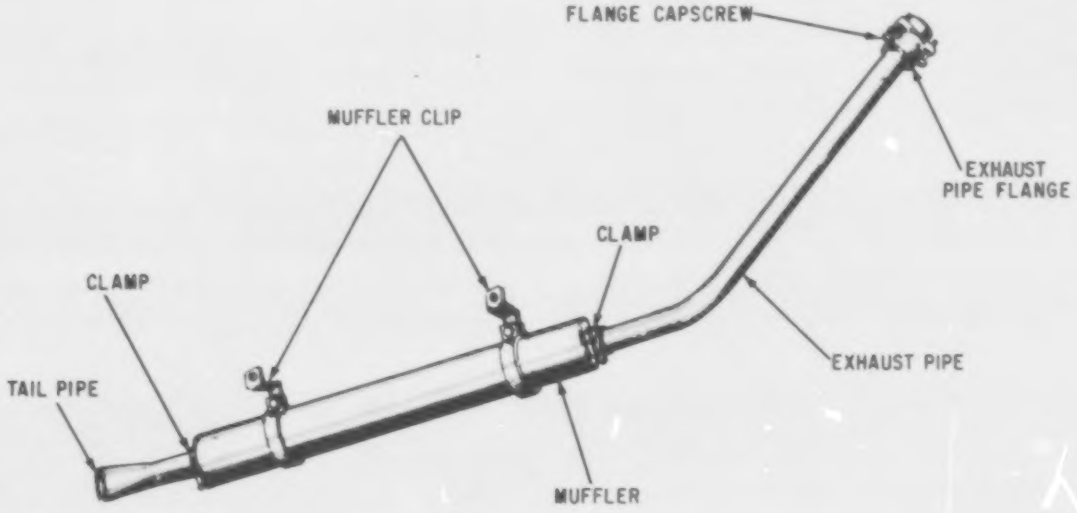


Figure 4-27.—Exhaust pipe, muffler, and tail pipe.

replaced also if suspected of being clogged with carbon particles or other foreign matter. Inability of the engine to develop maximum power, difficult starting, and operation of the engine at higher than normal temperatures may indicate clogging of either the muffler or another part of the exhaust system.

The muffler TAIL PIPE or OUTLET PIPE, which extends to the rear of the vehicle (or over the cab on some construction equipment, and trucks), should be kept open so that the exhaust gases can escape easily. A pinched or partly closed tail pipe can affect engine operation to the extent that the engine may stop. Unless the used gases are removed from the cylinders, a fresh mixture cannot enter.

Rain caps should be installed on exhaust pipes which extend upward. These caps prevent rain and dirt from entering the exhaust pipe and engine when the equipment is not being used, thus eliminating starting and operating problems. The exhaust pipe of equipment with turbochargers must be sealed when being transported unless the engine is left running. This prevents damage to the turbocharger, which could be caused by air flowing into the vertical exhaust pipe and turning the turbocharger with no lubrication.

GASOLINE ENGINE EMISSIONS

Air pollution should be a major concern of every American citizen. In many large metropolitan areas where traffic is congested and industry is concentrated, contamination of the air has become a serious problem.

The major causes of air pollution are industry and the gasoline engine. As a Construction Mechanic, you are directly concerned with the prevention of pollution by the gasoline engine and its fuel system.

To help reach this goal, you need to know what these polluting substances (emissions) are, where in the gasoline engine and fuel system they originate, how they are controlled, and how controlling devices (emission controls) work to make the vehicles safe for use in our environment.

The emissions from the gasoline fuel system and engine originate from four sources: the fuel tank, carburetor, crankcase, and exhaust. Each source requires its own controlling device.

Fuel systems on older models of gasoline engines were vented to the atmosphere. This method of ventilation allowed fuel vapors containing hydrogen and carbon (HC) to escape. When combined, HC and oxides of nitrogen (NO_x) cause smog in areas where there is a large volume of vehicle traffic. This smog causes reduced vision and irritation to the eyes and respiratory system.

Many changes have been made to gasoline-powered equipment in recent years to reduce the emissions and reverse this trend.

All gasoline engines you will encounter today have had some type of emission control devices installed. They will in one way or another affect the engines' operation and maintenance procedures. In order for you to perform the necessary maintenance on these engines, it is important that you consult the manufacturer's manual for the specific engine and application you are working on. This will allow you to make repairs and adjustments without reducing the effectiveness of these devices.

THE DIESEL FUEL SYSTEM

Like the gasoline engine, the diesel engine is an internal combustion engine using either a 2- or 4-stroke cycle (discussed in chapter 2). Power is obtained by the burning or combustion of fuel within the engine cylinders. The diesel engine does not use a carburetor because the diesel fuel is mixed in the engine cylinder with the compressed air.

Compression ratios in the diesel engine range between 14:1 and 19:1. This high ratio causes increased compression pressures of 400 to 600 psi, and cylinder temperatures reach 800° to 1200°F. At the proper time, the diesel fuel is injected into the cylinder by a fuel injection system, which usually consists of a pump, fuel lines, and injector or nozzle. When the fuel oil enters the cylinder it will ignite because of the high temperature. The diesel engine is known as a COMPRESSION-IGNITION engine, while the gasoline engine is a SPARK-IGNITION engine.

Figure 4-28 shows the comparison of the four strokes of a 4-cycle diesel and a 4-cycle gasoline engine.

The speed of a diesel engine is controlled by the amount of fuel injected into the cylinders; in a gasoline engine the speed of the engine is controlled by the amount of air admitted into the carburetor.

Mechanically, the diesel engine is similar to the gasoline engine. The intake, compression, power, and exhaust strokes occur in the same order. The arrangement of the pistons, connecting rods, crankshaft, and engine valves are about the same. The diesel engine is also classified as INLINE or V-TYPE.

In comparison to the gasoline engine, the diesel engine produces more power per pound of fuel, is more reliable, has lower fuel consumption per horsepower per hour, and presents less of a fire hazard.

These advantages are partially offset by high initial cost, heavier construction needed for its high compression pressures, and the difficulty in starting which results from these pressures.

DIESEL FUEL

Diesel fuel is heavier than gasoline because it is obtained from the residue of the crude oil after the more volatile fuels have been removed. As with gasoline, the efficiency of a diesel fuel varies with the type of engine in which it is used. By distillation, cracking, and blending of several oils, a suitable diesel fuel can be obtained for all engine operating conditions. Slow speed diesels use a wide variety of heavy fuels; high speed diesel engines require a lighter fuel. Using a poor or an improper grade of fuel can cause hard starting, incomplete combustion, a smoky exhaust, and engine knocks.

The high injection pressures needed in the diesel fuel system result from close tolerances in the pumps and injectors. These tolerances make it necessary for the diesel fuel to have sufficient lubrication qualities to prevent rapid wear or damage. It must also be clean, mix rapidly with the air, and burn smoothly to produce an even thrust on the piston during combustion.

The properties to consider in selecting a fuel for a diesel engine are volatility, cleanliness, viscosity, and ignition quality.

Volatility

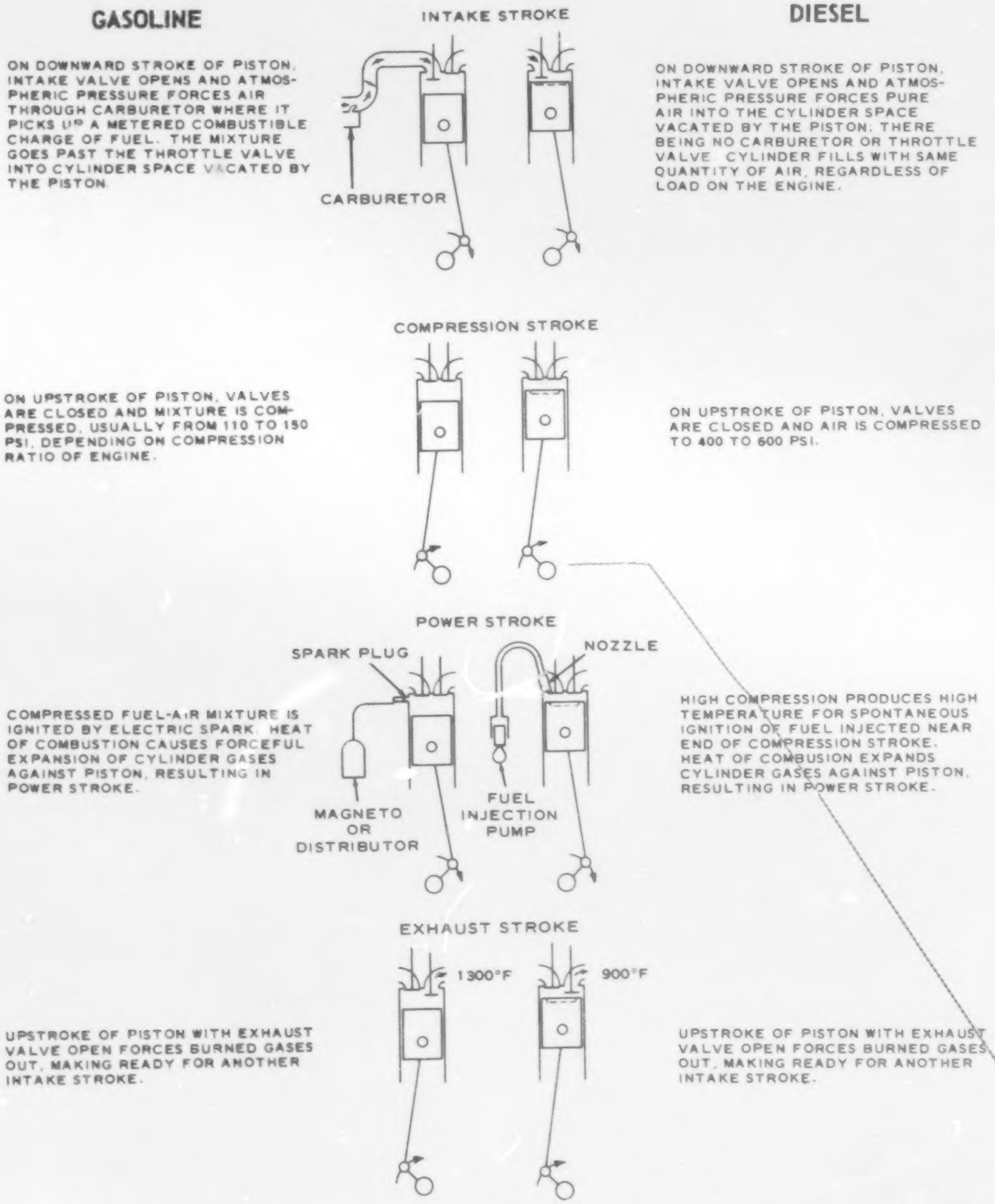
The volatility of a diesel fuel is measured by the 90-percent distillation temperature. This is the temperature at which 90 percent of a sample of the fuel has been distilled off. The lower this temperature, the higher the volatility of the fuel. In small diesel engines, a fuel of high volatility is more necessary than in large engines if there is to be low fuel consumption, low exhaust temperature, and little exhaust smoke.

Cleanliness

Cleanliness of diesel fuel is very important. Fuel should not contain more than a trace of foreign substances; otherwise, fuel pump and injector difficulties will develop. Because it is heavier and more viscous, diesel fuel will hold dirt particles in suspension for longer periods than will gasoline. In the refining process, not all foreign matter can be removed, and harmful matter like dirt and water can get into the fuel while it is being handled. Water especially will rust an engine. Water will also cause hard starting and misfiring. Dirt will clog injectors and spray nozzles and may cause an engine to misfire or stop altogether.

Viscosity

The viscosity of fuel is the measure of its resistance to flow. Viscosity is expressed by the number of seconds required for a certain volume of fuel to flow through a hole of a certain diameter at a given temperature. The viscosity of diesel fuel must be low enough to flow freely at low temperatures, yet high enough to lubricate the pump and injector plungers properly and lessen the possibility of leakage at the pump plungers and dribbling at the injectors. Viscosity is measured by an instrument called the SAYBOLT VISCOSIMETER and is expressed in SAYBOLT SECONDS, UNIVERSAL (SSU).



GASOLINE

DIESEL

INTAKE STROKE

ON DOWNWARD STROKE OF PISTON, INTAKE VALVE OPENS AND ATMOSPHERIC PRESSURE FORCES AIR THROUGH CARBURETOR WHERE IT PICKS UP A METERED COMBUSTIBLE CHARGE OF FUEL. THE MIXTURE GOES PAST THE THROTTLE VALVE INTO CYLINDER SPACE VACATED BY THE PISTON.

ON DOWNWARD STROKE OF PISTON, INTAKE VALVE OPENS AND ATMOSPHERIC PRESSURE FORCES PURE AIR INTO THE CYLINDER SPACE VACATED BY THE PISTON. THERE BEING NO CARBURETOR OR THROTTLE VALVE. CYLINDER FILLS WITH SAME QUANTITY OF AIR, REGARDLESS OF LOAD ON THE ENGINE.

COMPRESSION STROKE

ON UPSTROKE OF PISTON, VALVES ARE CLOSED AND MIXTURE IS COMPRESSED, USUALLY FROM 110 TO 150 PSI, DEPENDING ON COMPRESSION RATIO OF ENGINE.

ON UPSTROKE OF PISTON, VALVES ARE CLOSED AND AIR IS COMPRESSED TO 400 TO 600 PSI.

POWER STROKE

COMPRESSED FUEL-AIR MIXTURE IS IGNITED BY ELECTRIC SPARK. HEAT OF COMBUSTION CAUSES FORCEFUL EXPANSION OF CYLINDER GASES AGAINST PISTON, RESULTING IN POWER STROKE.

HIGH COMPRESSION PRODUCES HIGH TEMPERATURE FOR SPONTANEOUS IGNITION OF FUEL INJECTED NEAR END OF COMPRESSION STROKE. HEAT OF COMBUSION EXPANDS CYLINDER GASES AGAINST PISTON, RESULTING IN POWER STROKE.

EXHAUST STROKE

UPSTROKE OF PISTON WITH EXHAUST VALVE OPEN FORCES BURNED GASES OUT, MAKING READY FOR ANOTHER INTAKE STROKE.

UPSTROKE OF PISTON WITH EXHAUST VALVE OPEN FORCES BURNED GASES OUT, MAKING READY FOR ANOTHER INTAKE STROKE.

81.333

Figure 4-28.—Comparison of sequence of events in diesel and gasoline 4-cycle engines.

Ignition Quality

The ignition quality of a diesel fuel is its ability to ignite when it is injected into the compressed air within the engine cylinders. Ignition quality is measured by the CETANE RATING of the fuel. A cetane number is obtained by comparing the ignition quality of a given diesel fuel with that of a reference fuel of known cetane number in a test engine. This reference fuel is a mixture of alphamethylnapthalene, which is difficult to ignite alone, and cetane, which will ignite readily at temperatures and pressures comparable to those in the cylinders of a diesel engine. The cetane rating indicates the percentage of cetane in a reference fuel which will just match the ignition quality of the fuel being tested. The higher cetane numbers indicate more efficient fuels. The large, slow diesels can use 30 cetane fuel, but the high speed diesels must use at least a 40 cetane fuel, while some require as high as a 60 cetane fuel.

The ignition quality of a diesel fuel depends also on its FLASH POINT and its FIRE POINT. The flash point is the temperature to which the fuel vapors must be heated to flash or ignite. The minimum flash point for diesel fuel is 150°F. A fuel having too low a flash point is dangerous both to handle and to store.

The fire point is that temperature at which the fuel vapors will continue to burn after being ignited. It is usually 50 to 120 degrees higher than the flashpoint.

You will sometimes hear knocks in diesel engines. They are believed to be caused by the rapid burning of the fuel that accumulates during the delay period between injection and ignition. This delay is known as IGNITION LAG or IGNITION DELAY. When the fuel is injected into the cylinders, it must vaporize and be heated to the flash point to start combustion. The lag between vaporization and flash point depends upon the ignition quality of the fuel and the speed of the engine and its compression ratio. In high speed engines the delay varies from 0.0012 to 0.0018 of a second. Ignition lag decreases with the increase in engine speed because of a swifter air movement in the cylinders that makes the injected fuel heat better. Diesel combustion chambers are designed to provide swift movement of air in the cylinder. The air assists in providing a uniform mixture when the fuel is injected into the cylinder.

COMBUSTION CHAMBER DESIGN

Several types of combustion chambers are used in modern diesel engines. They are designed to create turbulence in the cylinder in order to mix the air and fuel effectively. All modern combustion chambers may be classified under one of the following four designs: OPEN type, PRECOMBUSTION type, TURBULENCE chambers, and HYPERCYCLE combustion chambers. In construction equipment, the most common types are the open combustion chamber and the precombustion chamber.

Open Combustion Chamber

The open combustion chamber (fig. 4-29) is the simplest form of chamber. Due to the design

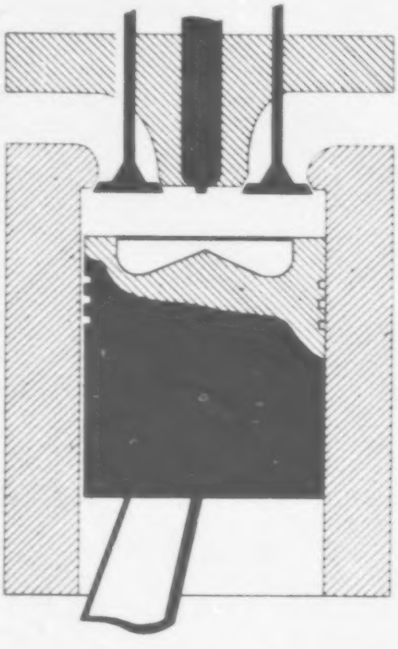


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Figure 4-29.—Diesel engine open combustion chamber.

of the piston crown, turbulence is generated as the piston comes up on the compression stroke. The injector is mounted in the cylinder head so that the end extends slightly below the bottom. The fuel is injected directly into the combustion space formed by the top of the piston and the cylinder head. The open chamber requires higher injection pressures and a greater degree of atomization to obtain the proper air-fuel mixture than the other types of combustion chambers. To equalize combustion in the combustion chamber, it uses a multiple orifice-type injector tip for effective penetration and angle of spray.

Precombustion Chamber

Figure 4-30 shows a diagram of a precombustion chamber. This chamber is usually separate from the cylinder head, but is screwed or pressed into the opening provided in the cylinder head. The precombustion chamber is water cooled because it extends through the water jacket and into the bottom of the cylinder head. It must be sealed at both ends to prevent water leakage. As the piston moves up on the compression stroke, a small part of the compressed air enters the precombustion chamber where it swirls rapidly within a small space. The fuel nozzle is of the single hole type and is mounted into the precombustion chamber. As it is injected from a single hole nozzle, the fuel is only slightly atomized and depends on this highly turbulent air for further atomization and ignition. High pressure builds up inside the precombustion chamber as ignition begins. This pressure causes the remaining fuel to vaporize and, at the same time, move into the main combustion space.

Turbulence Chamber

The turbulence chamber (fig. 4-31) is similar in appearance to the precombustion chamber, but its function is different. There is very little clearance between the top of the piston and the head, so that a high percentage of the air between the piston and the cylinder head is forced into the turbulence chamber during the compression stroke. The chamber is usually spherical, and the small opening through which the air must pass causes an increase in air velocity as it enters the chamber. This turbulence speed is about 50 times crankshaft

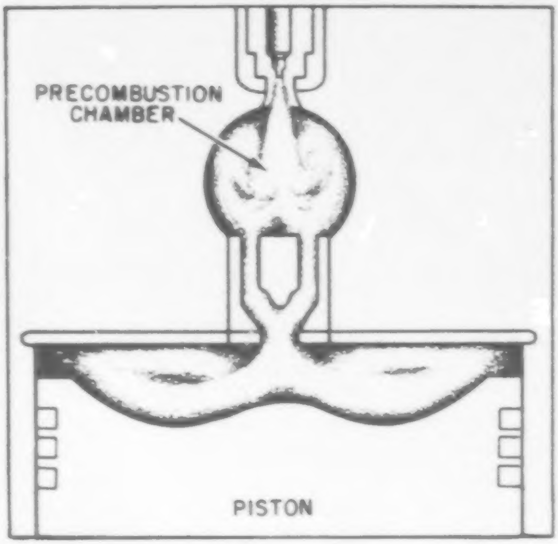

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Figure 4-30.—Diesel engine precombustion chamber.

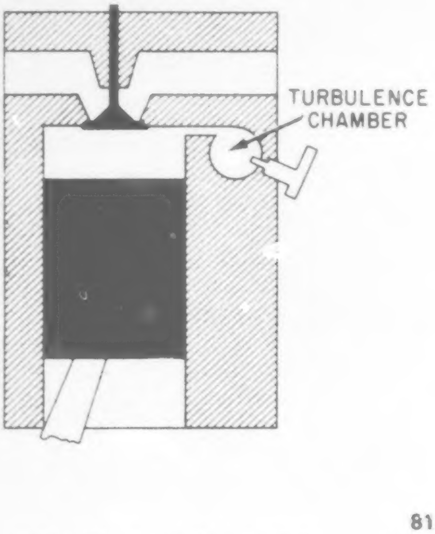

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Figure 4-31.—Diesel engine turbulence combustion chamber.

speed. The fuel injection is timed to occur when the turbulence in the chamber is greatest. This insures a thorough mixing of the fuel and air, causing the greater part of combustion to take place in the turbulence chamber. The pressure created by the expansion of the burning gases is the force that drives the piston downward on the power stroke.

Hypercycle Combustion Chamber

The hypercycle combustion chamber encountered by the Construction Mechanic is found in the multifuel engine used on tactical military vehicles. The engine is designed to burn various grades of fuel. However, the use of fuels other than diesel or jet fuel (JP-5) will severely shorten the engine's life.

The hypercycle combustion chamber is located in the crown of the piston. A small amount of fuel is injected directly into this chamber where combustion starts and moves upward as the fuel burning continues. Figure 4-32 illustrates the action which takes place during each stroke of an engine using the hypercycle combustion chamber.

GOVERNORS

The speed and the power output of an engine are determined by the combustion process in the cylinders. Since combustion depends upon air and fuel, the speed and the output of an engine can be controlled by regulating the amounts of air and fuel supplied for the combustion process.

In diesel engines, a varying amount of fuel is mixed with a constant amount of compressed air inside the cylinder. A full charge of air enters the cylinder during each intake event. Since the quantity of air admitted is constant, combustion and, in turn, speed and power output are controlled by regulating the amount of fuel injected into the cylinders.

Control of Engine Speed and Power

In a gasoline engine, speed and output are controlled by regulating the amount of air flowing into the cylinders of the engine. The carburetor is designed to control the airflow. The amount of air and its velocity, in turn, control the quantity of fuel with which the air is mixed before the mixture enters the cylinders.

The quantity and velocity of air flowing to the cylinders is controlled by the throttle valve. By operating the valve, you admit more or less air to the engine, and the carburetor automatically supplies the gasoline necessary to maintain the correct fuel-air ratio. Regulation of fuel or air supply by manual throttle control is adequate when engine speed and output requirements remain rather constant. However, the requirements of most engines used by the Navy vary because of fluctuating loads. The conditions under which construction equipment engines and the engine of a generating unit operate are examples of fluctuating loads. In road building, construction equipment constantly carries heavy loads outbound, but returns with no load. In the case of a generating unit, the demands for electricity are variable. Manual throttle control is not adequate to hold engine speed reasonably constant during such fluctuations in load. For this reason, a speed control device, or governor, is provided to prevent the engine from overspeeding and to allow the engine to meet changing load conditions.

Relation of Governor to Fuel System

Even though it is not a part of the fuel system, a governor is directly related to this system since it functions to regulate speed by control of the fuel or of the fuel-air mixture, depending upon the type of engine. In diesel engines, governors are connected in the linkage between the throttle and the fuel injectors. The governor acts, through the fuel injection equipment, to regulate the amount of fuel delivered to the cylinders. As a result, the governor holds engine speed reasonably constant during fluctuations in load. Since the speed and output of a gasoline engine depend on the amount of fuel-air mixture available, governors, when used on these engines, are so connected

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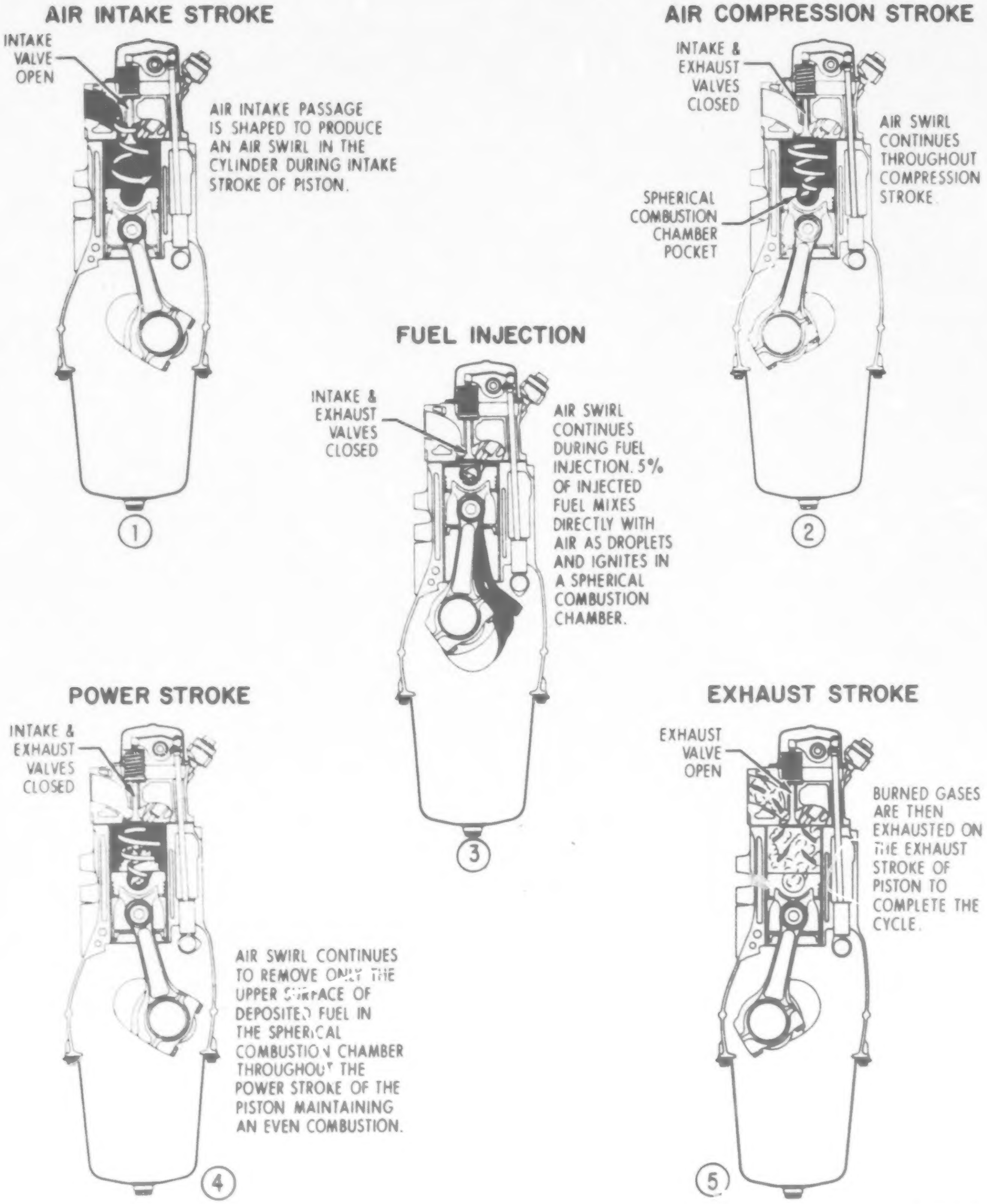
AIR INTAKE STROKE
INTAKE VALVE OPEN
AIR INTAKE PASSAGE IS SHAPED TO PRODUCE AN AIR SWIRL IN THE CYLINDER DURING INTAKE STROKE OF PISTON.
①
AIR COMPRESSION STROKE
INTAKE & EXHAUST VALVES CLOSED
AIR SWIRL CONTINUES THROUGHOUT COMPRESSION STROKE.
SPHERICAL COMBUSTION CHAMBER POCKET
②
FUEL INJECTION
INTAKE & EXHAUST VALVES CLOSED
AIR SWIRL CONTINUES DURING FUEL INJECTION. 5% OF INJECTED FUEL MIXES DIRECTLY WITH AIR AS DROPLETS AND IGNITES IN A SPHERICAL COMBUSTION CHAMBER.
③
POWER STROKE
INTAKE & EXHAUST VALVES CLOSED
AIR SWIRL CONTINUES TO REMOVE ONLY THE UPPER SURFACE OF DEPOSITED FUEL IN THE SPHERICAL COMBUSTION CHAMBER THROUGHOUT THE POWER STROKE OF THE PISTON MAINTAINING AN EVEN COMBUSTION.
④
EXHAUST STROKE
EXHAUST VALVE OPEN
BURNED GASES ARE THEN EXHAUSTED ON THE EXHAUST STROKE OF PISTON TO COMPLETE THE CYCLE.
⑤

115.221

Figure 4-32.—Hypercycle combustion chamber.

that they control the amount of the mixture flowing from the carburetor to the intake manifold.

Governors, like carburetors and fuel injection equipment, seem somewhat complicated unless one has a thorough understanding of the construction and operating principles of the equipment. As you progress through the Construction Mechanic rating, you will acquire, through practical experience and study, the knowledge necessary to understand the factors which may seem complicated at the present. For the time being, it is enough to understand the relationship of speed-control devices to the fuel system of an engine. For this reason, the information on governors which is given in this course is general in nature.

Speed-Regulating Governors for Diesel Engine

The type of load and the degree of control desired determine the kind of governor to be used on a diesel engine. Since all governors used on diesel engines control engine speed through the regulation of the quantity of fuel delivered to the cylinders, these governors may be classified under the general heading of speed-regulating governors. Governors used on diesel engines may also be classified in various other ways, such as according to the function or functions performed, the forces utilized in operation, and the means by which the governor operates the fuel-control mechanism.

Governors are designed to control engine speed under varying load conditions. Since the type of load and the degree of control desired vary from one type of installation to another, the primary function of a governor depends upon the requirements of a particular installation.

Some installations require that engine speed remain constant from a no-load to a full-load condition. Governors which function to maintain a constant speed, regardless of load, are called CONSTANT-SPEED governors. Governors which maintain any desired engine speed between idle and maximum speeds are classified as VARIABLE-SPEED governors. Speed-control devices which are designed to keep an engine from exceeding a specified maximum speed and from dropping below a specified minimum speed are classified as SPEED-LIMITING governors. (In some cases, speed-limiting governors function only to limit maximum speed.) Some engine installations require a control device that limits the load which the engine will handle at various speeds. Such devices are called LOAD-LIMITING governors.

A governor may also be designed to perform two or more of the functions just listed. In this case, the operating mechanisms which perform the various functions are combined in a single unit.

Spring-Loaded Centrifugal Governors

In most of the governors installed on diesel engines used by the Navy, the centrifugal force of rotating weights (flyballs) and the tension of a helical coil spring (or springs) are utilized in governor operation. On this basis, most of the governors used on diesel engines are generally called SPRING-LOADED CENTRIFUGAL governors.

In spring-loaded centrifugal governors, two forces oppose each other. One of these forces is the tension of a spring (or springs) which may be varied either by an adjusting device or by movement of the manual throttle. The other force is produced by the engine. Weights attached to the governor drive shaft are rotated, and a centrifugal force is created when the shaft is driven by the engine. The centrifugal force varies directly with the speed of the engine.

Transmitted to the fuel system through a connecting linkage, the tension of the spring (or springs) tends to increase the amount of fuel delivered to the cylinders. On the other hand, the centrifugal force of the rotating weights, through connecting linkage, tends to reduce the quantity of fuel injected. When the two opposing forces are equal, or balanced, the speed of the engine remains constant.

To illustrate how the centrifugal governor works, let us assume that an engine operates under load, and that the opposing forces in the governor are balanced, so that the engine speed is constant. If the load is increased, the engine speed decreases, resulting in a reduction in the centrifugal force of the flyballs. The spring tension then becomes the greater force and it acts on the fuel-control mechanism to increase the quantity of fuel delivered to the engine. The increase in fuel results in an increase in engine speed until balance of the forces is again reached.

When the load on an engine is reduced or removed, the engine speed increases and the centrifugal force within the governor increases. The centrifugal force then becomes greater than the spring tension and acts on the fuel control linkage to reduce the amount of fuel delivered to the cylinders. This causes the engine speed to decrease until a balance between the opposing forces is again reached and engine speed becomes constant.

Other Classifications of Governors

Governors are also classified according to the method by which fuel-control mechanisms are regulated. In some cases, the centrifugal force of the rotating weights regulates the fuel supply directly, through a mechanical linkage which operates the fuel-control mechanism. Other governors are designed so that the centrifugal force of the rotating weights regulates the fuel supply indirectly, by moving a hydraulic pilot valve which controls oil pressure. Oil pressure is then exerted on either side of a power piston which operates the fuel-control mechanism.

Governors which regulate the fuel supply directly (through mechanical linkage) are called MECHANICAL GOVERNORS; and those which control the fuel supply indirectly (through oil pressure) are called HYDRAULIC GOVERNORS. Simple governors of the mechanical and hydraulic types are shown in figures 4-33 and 4-34, respectively.

Note that in the illustration of the mechanical governor, the weights, or flyballs, are in an upright position. This indicates that the centrifugal force of the weights and the tension of the spring are balanced; in other words, the engine is operating at constant load and speed. In the case of the hydraulic governor, the positions of the parts indicate that the engine is responding to an increase in load with a resulting decrease in engine speed. Note that the weights tilt inward at the top. As engine speed decreases,

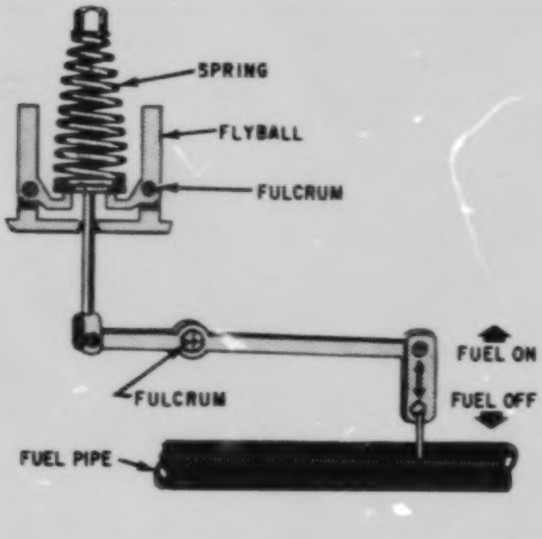

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Figure 4-33.–Simple mechanical governor.

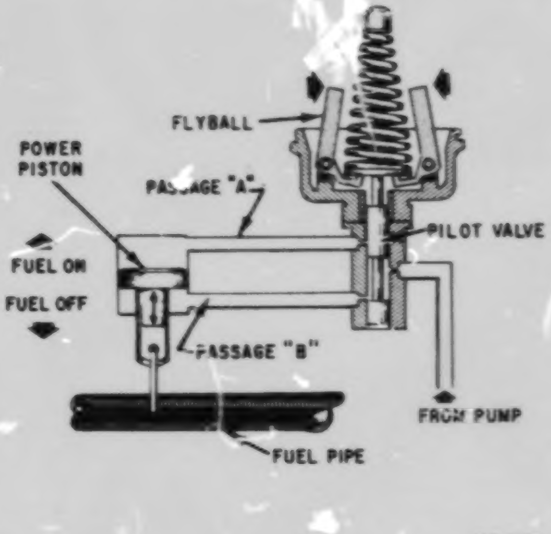

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Figure 4-34.–Simple hydraulic governor.

the spring tension overcomes the centrifugal force of these rotating weights. When the spring tension is greater than the centrifugal force of the flyballs, the governor mechanism acts to permit oil under pressure to force the piston to increase the fuel valve opening. The increased fuel supply causes an increase in engine power output and speed. The governor regulates the fuel supply so that enough power is developed to handle the increase in load.

Hydraulic governors are more sensitive than those of the mechanical type. Also, the design of a hydraulic governor enables a comparatively small governing unit to control the fuel mechanism of a large engine. The mechanical governor is used more often on small engines, which do not require extremely close regulation of the fuel. Hydraulic governors are more suitable to large engines, in which more accurate regulation of fuel is necessary.

Danger of Excessive Speed

Engines which are maintained in proper operating condition seldom reach speeds above those for which they are designed. However, there may be times when speeds become too high. The operation of an engine at excessive speeds is extremely dangerous. If the engine speed is high enough, the high inertia and centrifugal force developed may cause parts to become seriously damaged or even to fly apart. Therefore, it is essential that you know why an engine may reach a dangerously high speed, and how it may be brought under control when too much speed occurs.

Causes of Excessive Speed

In some 2-stroke cycle engines, lubricating oil may leak into the cylinders as a result of leaky blower seals or broken piping. Even though the fuel is shut off, the engine may continue to operate or even run away, as a result of this combustible material coming from the uncontrolled source. Engines in which lubricating oil may accumlate in the cylinders are generally equipped with an automatically operated mechanism which shuts off the intake air at the inlet passage to the blower. If no air shutoff mechanism is provided and shutting off the fuel will not stop an engine which is over-speeding, anything which can be placed over the engine's air intake to stop airflow, such as a piece of canvas or even a pair of dungarees, will stop the engine.

Excessive engine speeds more commonly result from an improperly functioning regulating governor than from any other cause. The usual method of accomplishing an emergency shutdown when the regulating governor fails to function properly is to shut off the fuel oil supply to the cylinders. If this fails to slow the engine or stop it, the air supply to the engine must be cut off.

CAUTION: Do not risk personal injury to stop an overspeeding engine when all normal means have failed.

Stopping Fuel Supply

Shutting off the fuel supply to the cylinders of an engine may be done in various ways. The fuel-control mechanism may be forced to the NO FUEL position; the fuel line may be blocked by closing a valve; the pressure in the fuel injection line may be relieved by opening a valve; or the mechanical movement of the injection pump may be prevented. These methods of shutting off the fuel supply may be done either manually or automatically.

Overspeed Safety Devices

Automatic operation of fuel and air control mechanisms is accomplished by overspeed safety devices. As emergency controls, these safety devices operate only in the event the regular speed governor fails to maintain engine speed within the maximum design limit. Devices which function to bring an overspeeding engine to a full stop by completely shutting off the fuel or air supply are generally called OVERSPEED TRIPS. Devices which function to reduce the excessive speed of an engine, but allow the engine to operate at safe speeds, are called OVERSPEED GOVERNORS.

All overspeed governors and trips depend upon a spring-loaded centrifugal governor element for their operation. In overspeed devices, the spring tension is great enough to overbalance the centrifugal force of the weights until the engine speed rises above the desired maximum. When an excessive speed is reached, the centrifugal force overcomes the spring tension and operates the mechanism which stops or limits the fuel or air supply.

Governors as Safety Devices

When a governor serves as the safety device, the actual operation of the fuel or air control mechanism by centrifugal force may be brought about directly, as in a mechanical governor, or indirectly, as in a hydraulic governor. In the case of an overspeed trip, the shutoff control is operated by a power spring. The spring is placed under tension when the trip is manually set, and held in place by a latch. If the maximum speed limit is exceeded, a spring-loaded centrifugal weight moves out and trips the latch, allowing the power spring to operate the shutoff mechanism.

DIESEL FUEL SYSTEM COMPONENTS

The diesel fuel system is similar to the gasoline system in tank and fuel line construction only. Each manufacturer has his own method of transferring the fuel and creating the high pressure required for injection of the fuel into the cylinders.

FUEL TANKS

The diesel fuel tank is mounted directly on the chassis of construction equipment because of its weight (when filled) and to prevent movement of the tank when the equipment is operated over rough terrain. Its location also depends on the type of equipment and the equipment's use. On equipment used for ground clearing and earthwork, the tank is mounted where it has less chance of being damaged by foreign objects or striking the ground. Fuel tank caps are usually threaded internally and screw onto the tank filler pipe. Most fuel caps are equipped with a sealing gasket and vent hole.

FUEL GAGES

The electric gages used on diesel fuel tanks are the same type as used in the gasoline fuel system. Some manufacturers use a bayonet type gage permanently attached to the filler cap of the fuel tank or installed under the fuel cap. These are graduated and the fuel level is checked by the same method as oil in an engine.

FUEL FILTERS

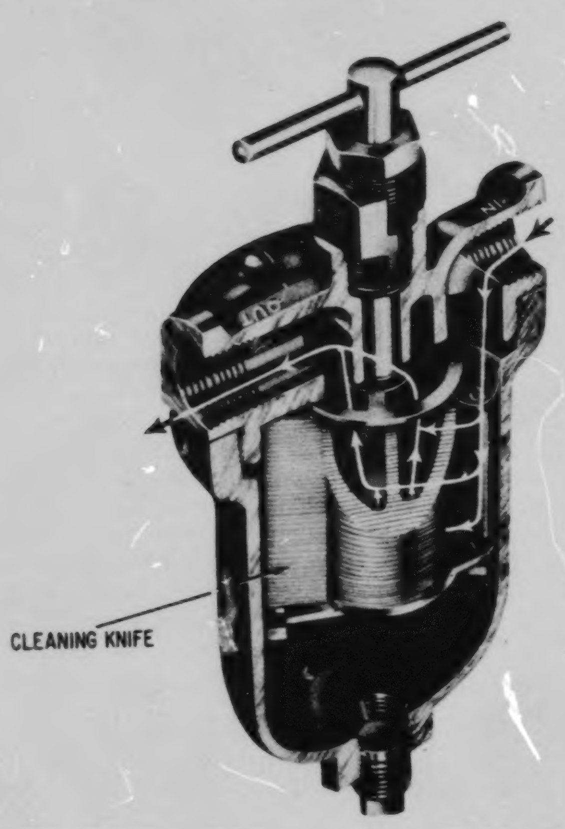
Fuel filters are built into the fuel supply systems of diesel engines to filter any abrasive impurities that may be in the fuel. These impurities may have been difficult to eliminate during the process of refining, or they may enter the fuel tank through careless refueling. Whatever the source, these impurities must be removed to protect the closely fitted parts in the pumps and nozzles.

Most diesel engines have two filters in the fuel supply system. The primary (coarse) filter is usually located between the supply tank and the fuel supply pump, and the secondary (fine) filter between the fuel supply pump and the injection pump. Additional filtering elements are frequently installed between the injection pump and the nozzle.

Diesel fuel oil filters are referred to as FULL-FLOW filters, since all the fuel must pass through the filters before reaching the injection pumps. Filters must be inspected regularly and cleaned or replaced, if their maximum efficiency is to be maintained. ALL METAL-DISK filters are cleanable, but most cloth or fabric elements must be replaced when they become dirty.

Metal-Disk Filter

The metal-disk filter shown in figure 4-35 is made of a series of laminated disks placed within a large bowl, which acts as a settling chamber for the fuel and encloses the disks or strainer assembly. Fuel enters the filter at the top inlet connection and, flowing down, goes between the



81.151
Figure 4-35.—Metal-disk fuel filter.

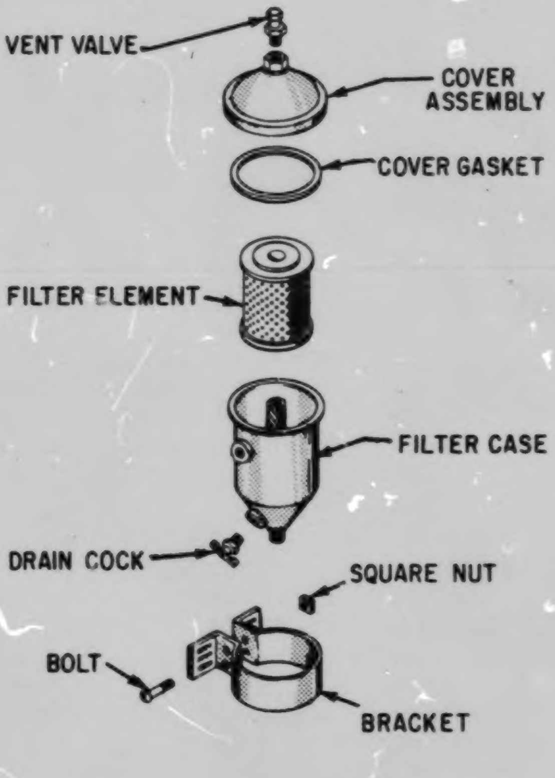
disks, and then up a central passage to the outlet connection at the top. Dirt and foreign matter cannot pass between the disks and are deposited at the outer rim. The clearance between the disks (0.003 inch) is small enough to prevent the passage of water. This is possible because water, when present in gasoline or oil, forms small globules that are too large to pass between the disks. The filter shown in figure 4-35 is the same as the one mentioned above except that a cleaning knife is added. Solids larger than 0.005 inch remain on the outside of the element, and the cleaning knife scrapes these deposits off the filtering disks. The solids fall to the bottom of the filter housing, where they can be removed through the drain plug hole. A ball relief valve in the filter cover enables the fuel oil to bypass the filter element if the disks become clogged. A diesel fuel oil filter usually has an air vent for releasing any air which might accumulate in the filter.

Fabric Filter

Fabric filters, because of their greater filtering qualities, are used principally as main filters for protecting the fuel injection pump. Most fuel systems now use microporous paper fuel filters (fig. 4-36) which are of the replaceable cartridge type.

FUEL SUPPLY PUMP

Fuel injection pumps must be supplied with fuel oil under pressure because they have



81.513
Figure 4-36.—Fuel filter assembly with replaceable element.

insufficient suction ability. All diesel injection systems require a supply pump to transfer fuel from the supply tank, through the filters and lines to the injection pumps. Two types of supply pumps used on diesel engines today are the gear type and the vane type.

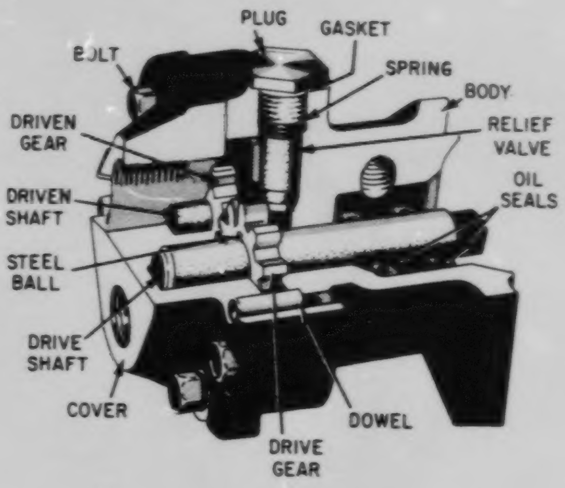
Gear Pump

The simple GEAR PUMP (fig. 4-37) has two spur gears which mesh together; one is the driving gear, the other the driven gear. Clearances between the gear faces and casing are only a few thousandths of an inch. When the gears turn, liquid in the spaces between the unmeshed teeth, at the suction side of the pump, is carried by the teeth towards the sides. Then the liquid is trapped between the tooth pockets and the casing, and carried through to the discharge side of the pump. The liquid entering the discharge side cannot return to the suction side because the meshing teeth at the center force the liquid out of the tooth pockets.

Vane Pump

In the VANE-TYPE PUMP (fig. 4-38 and 4-39) a steel rotor and shaft, one end supported in the pump cover, revolve in the body, the bore of which is eccentric to the rotor. Two sliding vanes are placed 180 degrees apart in slots in the rotor, and are pressed against the body bore by springs in the slots. When the shaft is rotated, the vanes pick up fuel at the inlet port and carry it around the body to the outlet side, where the fuel is discharged. Pressure is produced by the wedging action of the fuel as it is forced toward the outlet port by the vane. A spring-loaded relief valve is provided in the cover of the pump, connecting the inlet and outlet ports. This valve opens at a pressure of approximately 55 psi. Its purpose is to relieve excessive pump pressure which will build up if fuel lines or filters become clogged. When the valve opens, fuel passes from the discharge side (pressure side) to the suction side of the pump.

The remaining task to be accomplished by the fuel system is to provide the proper quantity of fuel to the engine's cylinders. This is done differently by each manufacturer and is referred to as FUEL INJECTION.



81.370

Figure 4-37.–Typical gear fuel pump assembly.

FUEL INJECTION

Diesel fuel injection systems must accomplish five particular functions: Meter, inject, time, atomize, and create pressure. A description of these functions follows:

1. METER–Accurately measure the amount of fuel to be injected.
2. INJECT–Force and distribute the fuel into the combustion chamber.
3. TIME–Injection of the fuel must start and stop at the proper time.
4. ATOMIZE–Break the fuel up into fine particles.
5. CREATE PRESSURE–Create the necessary high pressure for injection.

You can remember these functions by the initials, MITAC. All five of these functions are necessary for complete and efficient combustion.

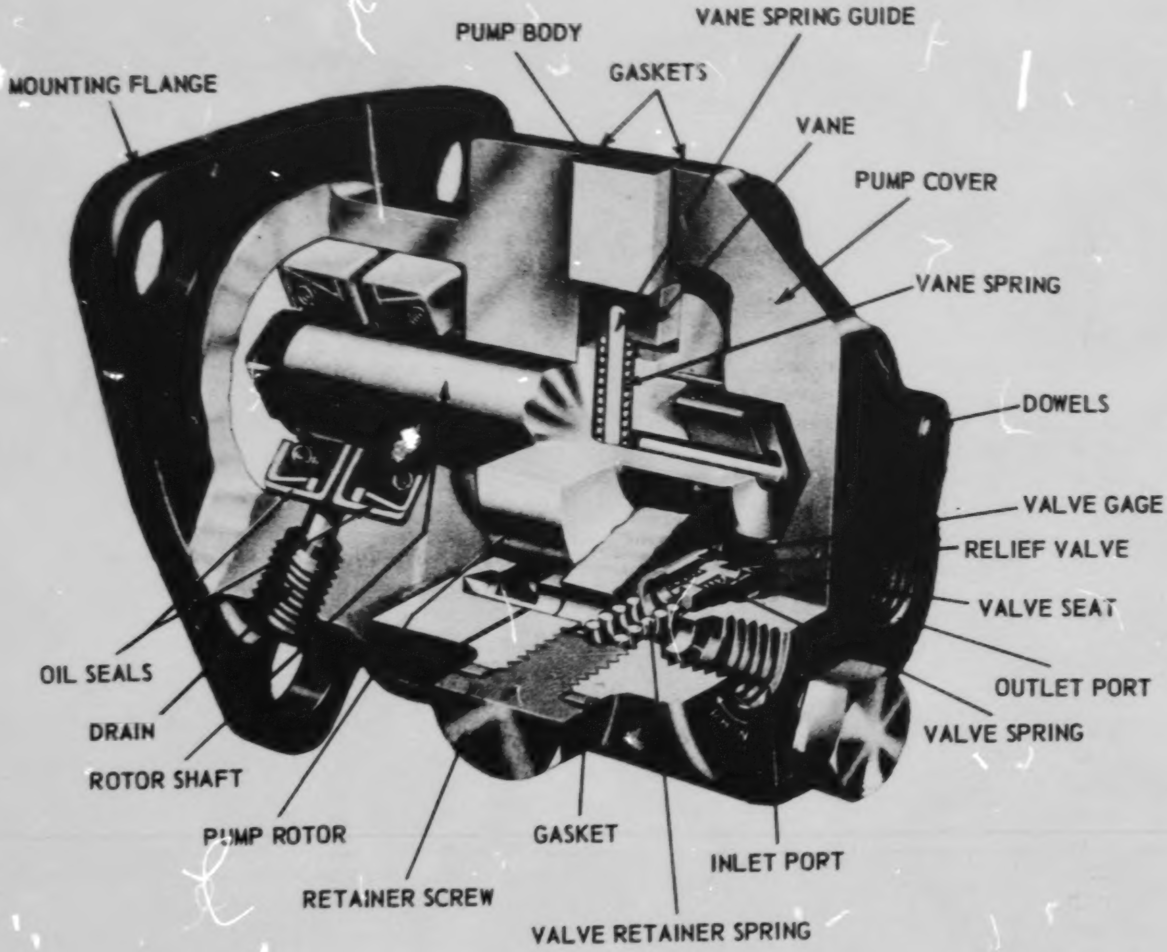

PUMP BODY
VANE SPRING GUIDE
MOUNTING FLANGE
GASKETS
VANE
PUMP COVER
VANE SPRING
DOWELS
VALVE GAGE
RELIEF VALVE
VALVE SEAT
OUTLET PORT
VALVE SPRING
OIL SEALS
DRAIN
ROTOR SHAFT
PUMP ROTOR
GASKET
INLET PORT
RETAINER SCREW
VALVE RETAINER SPRING
81.149

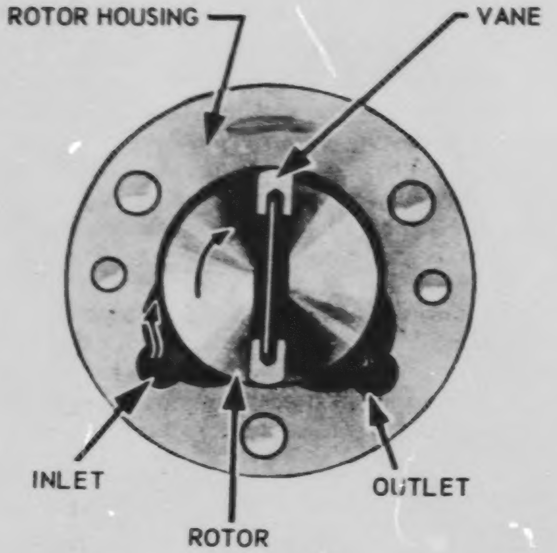
Figure 4-38.—Cutaway view of vane-type fuel pump.

Metering

Accurate metering or measuring of the fuel means that, for the same fuel control setting, the same quantity of fuel must be delivered to each cylinder for each power stroke of the engine. Only in this way can the engine operate at uniform speed with a uniform power output. Smooth engine operation and an even distribution of the load between the cylinders depend upon the same volume of the fuel being admitted to a particular cylinder each time it fires; and upon equal volumes of fuel being delivered to all cylinders of the engine.

Injection Control

A fuel system must also control the rate of injection. The rate at which fuel is injected determines the rate of combustion. The rate of injection at the start should be low enough that excessive fuel does not accumulate in the cylinder during the initial ignition delay (before combustion begins). Injection should proceed at



81.150

Figure 4-39.–Vanes and rotor in housing of a vane-type fuel pump.

such a rate that the rise in combustion pressure is not too great, yet the rate of injection must be such that fuel is introduced as rapidly as possible in order to obtain complete combustion. An incorrect rate of injection affects engine operation in the same way as improper timing. When the rate of injection is too high, the results are similar to those caused by a too early injection; when the rate is too low, the results are similar to those caused by a too late injection.

Timing

In addition to measuring the amount of fuel injected, the system must properly time injection to insure efficient combustion so that maximum energy can be obtained from the fuel. When the fuel is injected too early in the cycle, ignition may be delayed because the temperature of the air at this point is not high enough. An excessive delay, on the other hand, gives rough and noisy operation of the engine, and also permits some fuel to be lost due to the wetting of the cylinder walls and piston head. This, in turn, results in poor fuel economy, high exhaust gas temperature, and smoke in the exhaust. When fuel is injected too late in the cycle, all the fuel will not be burned until the piston has traveled well past top center. When this happens, the engine does not develop its maximum power, the exhaust is smoky, and the fuel consumption is high.

Atomization of Fuel

As used in connection with fuel injection, atomization means the breaking up of the fuel, as it enters the cylinder, into small particles which form a mistlike spray. Atomization of the fuel must meet the requirements of the type of combustion chamber in use. Some chambers require very fine atomization; others function with coarser atomization. (Because of the design of the multifuel hypercycle chamber, discussed earlier in this chapter, atomization is accomplished differently in chambers so designed.) Proper atomization makes it easier to start the burning process, and insures that each minute particle of fuel is surrounded by particles of oxygen with which it can combine.

Atomization is generally obtained when the liquid fuel, under high pressure, passes through the small opening (or openings), in the injector or nozzle. As the fuel enters the combustion space, high velocity is developed because the pressure in the cylinder is lower than the fuel pressure. The created friction, resulting from the fuel passing through the air at high velocity, causes the fuel to break up into small particles.

Creating Pressure

A fuel injection system must increase the pressure of the fuel enough to overcome compression pressures and to insure proper dispersion of the fuel injected into the combustion space. Proper dispersion is essential if the fuel is to mix thoroughly with the air and burn efficiently. While pressure is a chief contributing factor, the dispersion of the fuel is influenced, in part, by atomization and penetration of the fuel. (Penetration is the distance through which the fuel particles are carried by the motion given them as they leave the injector or nozzle.)

If the atomization process reduces the size of the fuel particles too much they will lack penetration. Too little penetration results in the small particles of fuel igniting before they have been properly distributed, or dispersed in the combustion space. Since penetration and atomization tend to oppose each other, a compromise in the degree of each is necessary in the design of fuel injection equipment, particularly if uniform distribution of fuel within the combustion chamber is to be obtained.

METHODS OF FUEL INJECTION

Basically, there are four methods used in today's diesel engines to accomplish the injection of fuel into the cylinders of the engine. These methods are: pump and nozzle, unit injection, distributor, and the pressure time (PT) system. Some engine manufacturers make and install their own fuel injection equipment. Others rely on manufacturers who specialize in fuel injection equipment and who design or modify their product to meet the requirements of the engine manufacturer.

CATERPILLAR FUEL INJECTION

The CATERPILLAR diesel engine uses the pump and nozzle injection system (fig. 4-40). Each pump measures the amount of fuel to be injected into the particular cylinder, produces the pressure for injection of the fuel, and times the exact point of injection. The injection pump plunger is lifted by cam action and returned by spring action. The metering of fuel is varied by the plungers turning in the barrels. These plungers are turned by governor action through a rack which meshes with the gear segments on the bottom of the pump plungers. Each pump is interchangeable with other injection pumps mounted on the pump housing.

The capsule-type nozzle is widely used in Caterpillar diesel engines. (See fig. 4-41.) The capsule-type nozzle is a sealed unit; therefore, it must be replaced when worn or damaged, although the tip opening may be cleaned with a special tool if clogged or dirty from carbon deposits.

The fuel is drawn from the tank by a gear-type transfer pump which delivers the fuel through filters into the fuel manifold in the fuel injection housing; from the fuel manifold, the fuel is supplied by separate passages to the individual fuel injection pumps. The fuel injection pumps deliver the proper amount of fuel through the fuel lines to the individual fuel injection valves at the proper time. From the injection valves the fuel enters the precombustion chambers. Ignition starts to take place in the precombustion chambers.

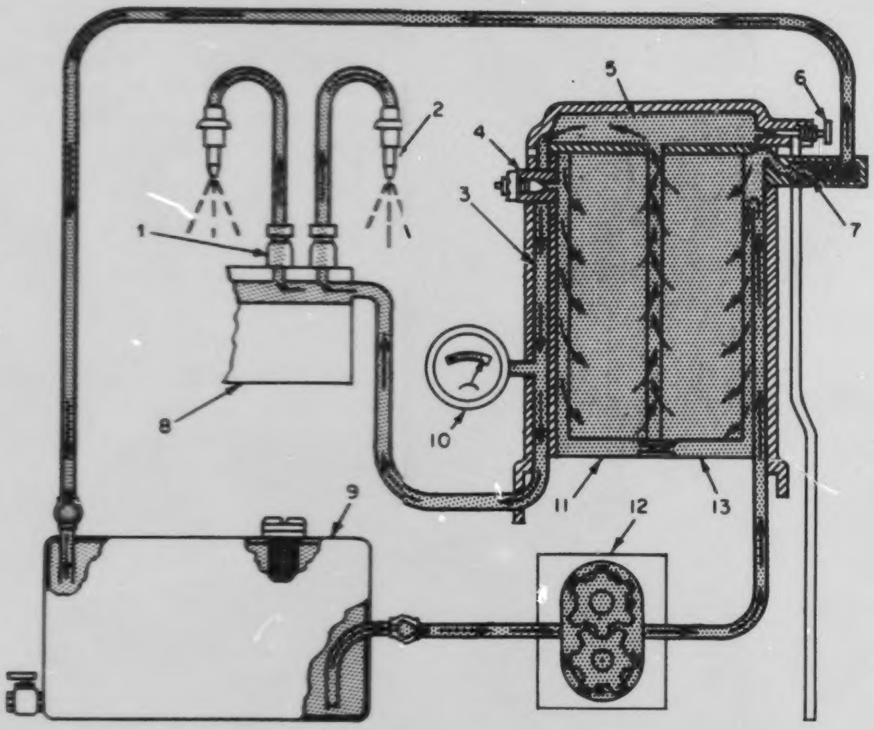
Removal of Injection Valves

When there is a requirement for removal of injection valves from the engine, clean all dust and dirt from the injectors and adjacent area to prevent dirt from entering the fuel system. Disconnect the fuel line and install a cap to prevent dirt and dust from entering the line. The valve and body can be lifted out after removing the retaining nut. The capsule is only finger tight on the body and is easily replaceable. When reinstalling the capsule, tighten the retaining nut to the manufacturer's specifications. A nut that is too loose, will allow leaks; one that is too tight will damage the capsule and cause poor injection.

Servicing Injection Pumps

Caterpillar injection pumps are interchangeable between cylinders on a particular engine and also between engines having the same bore, no matter whether the engines have four or six cylinders. However, each fuel injection pump assembly is machined and lapped to such exact clearances between the plunger and barrel that they must be used, removed, and replaced as a unit.

In removing fuel injection pumps, take every precaution to prevent dirt from entering the pump or pump housing. Before disconnecting



1. Injection pump.
2. Injection valve.
3. Passage.
4. Lower vent.
5. Upper chamber.
6. Upper vent.
7. Bypass valve.
8. Housing.
9. Tank.
10. Gage.
11. Housing.
12. Transfer pump.
13. Lower chamber.

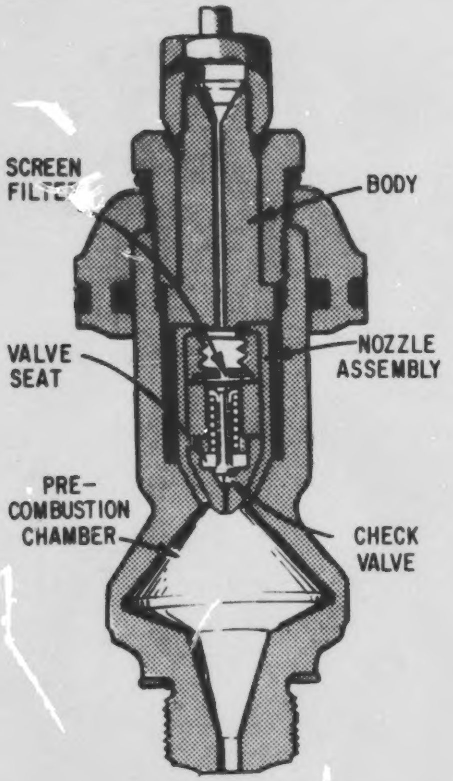
81.344

Figure 4-40.—Caterpillar fuel system.

any fuel lines or removing the inspection plate on the pump assembly housing, clean the top and sides of the housing thoroughly.

Start with the end pump of each bank when you are ready to remove them. With 4-cylinder engines there is only one bank of pumps, but with 6-cylinder engines the pumps are arranged in two banks of three each. The end pumps can be removed without disturbing the others. The center pump, for example two or five in a 6-cylinder arrangement, can be removed more easily if the pump next to it has been removed.

After disconnecting the fuel lines from the pumps, cover the openings immediately with the caps and plugs provided in the toolkit for this purpose. Then, after removing the coupling, retaining plates, and rack, take out the capscrews that hold the fuel injection pump clamps. Make sure the cap on the fuel outlet on top of the pump is in place while the pump is



81.345X

Figure 4-41.—Capsule-type fuel injection valve assembly.

disconnected from the engine. Remove the clamps that hold the fuel injection pumps to the housing. Now, the pumps can be lifted from the housing.

Lift out the pumps individually (see fig. 4-42). At first, lift them straight up only enough to clear the dowel pins. Then reach through the inspection opening and hold the pump plunger to keep it from sliding out of the barrel. To remove the pump entirely, it will be necessary to shift the pump slightly to one side to free the plunger from the slot in the lifter yoke.

When installing a fuel injection pump, again be careful that the pump plunger does not slide out of the barrel. Slide the end of the plunger into the slot on the lifter; lower the pump on the dowel pins and fasten in place.

If the pump plunger should fall out, wash it thoroughly with clean diesel fuel and then replace it in the pump barrel. As a check against accidental nicks and scratches that will shorten the life of the pump, rotate the plunger gear segment to make sure that the plunger turns freely and does not bind.

To synchronize pump operation, turn the gears on the pump plungers until the marked tooth of each gear faces outward toward the pump rack. Replace the pump so that the marked teeth of the plunger gears engage with the marked rack teeth.

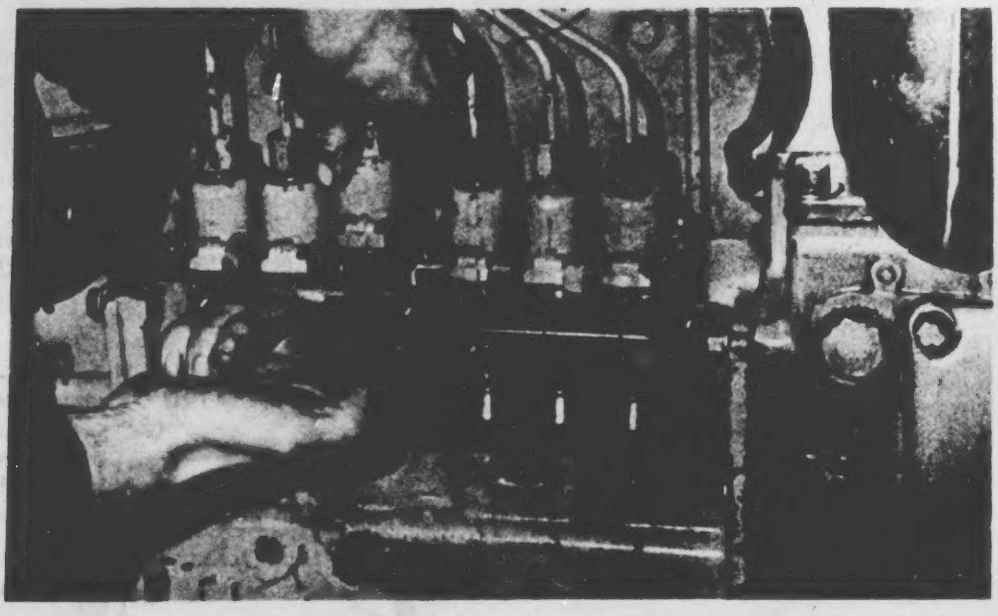
After sliding the rack into position, pull it out again to see that the marks are correctly alined. Then fasten the racks with the retaining plates; install the coupling (fork) between the rack and the fuel pump slide bar; replace the inspection cover; and connect the fuel lines.

Before starting the engine, bleed the fuel system to remove all air trapped in the fuel lines.

Governor Operation and Adjustments

The Caterpillar governor, like most governors used on diesels, is of the flyweight type (mechanical) and acts throughout the entire speed range of the engine. Once the desired speed is set by the position of the throttle, the governor acts automatically to maintain a relatively constant operating speed if the load changes. That is, all mechanical governors show a slight engine speed drop when a heavy load is first applied, and the engine will overspeed momentarily when the load is reduced. The throttle, connected to the governor by a suitable linkage, is merely a controlling device which adjusts the speed at which it then holds the engine.

The installation will vary with different engine models. On most Caterpillar tractors, however, the governors are vertically mounted and driven by the camshaft gear in the accessory housing at the front end of the injection pump housing. The throttle control is located where it is convenient for the operator. Figure 4-43 illustrates the working parts of a Caterpillar governor.



81.347

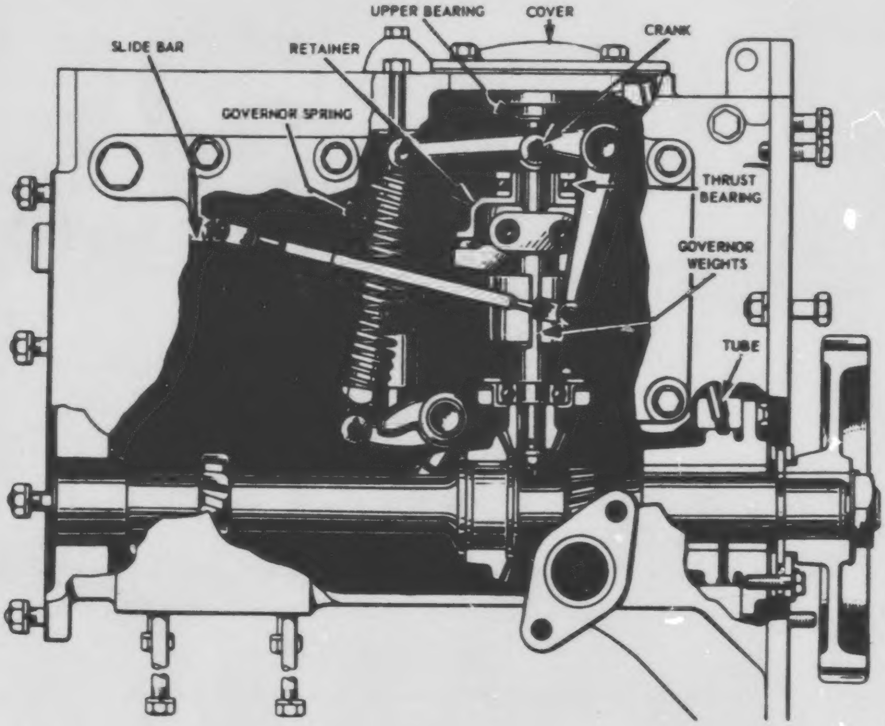
Figure 4-42.–Removing or replacing fuel injection pump on a 6-cylinder Caterpillar diesel.

In OPERATION, the governor shaft is driven off the engine accessory drive gear. As the engine speeds up, the flyweights (governor weights) hinged to the governor shaft swing out by centrifugal force. This action is opposed by the governor springs. The forces of the flyweights and governor springs act upon the slide bar to regulate the speed of the engine in accordance with the tension placed on the springs by the setting of the throttle. As the flyweights change their position with varying engine speeds, this movement is transmitted through the slide bar to the injection pump control rack. The control rack, in turn, rotates each pump plunger simultaneously to regulate the fuel delivered at the spray valves. Thus, as the operator changes the position of the throttle, the tension of the governor spring is changed, and the governor will maintain the engine speed called for by that particular throttle setting.

The governor is lubricated by oil from the engine lubricating system. At points where positive lubrication is necessary, such as bearings and bushings, oil is furnished under pressure through drilled passages in the housing or through tubes. Other parts of the governor are lubricated by the oil splash thrown off by the rotating parts.

Major adjustments are generally necessary only at the time the governor is completely disassembled, inspected, and repaired in the shop. This should be done by men who thoroughly understand the governor operation. However, it will sometimes be necessary to make idling and high-idle speed adjustments in the field. These adjustments can be made by removing the cover from the top of the governor (fig. 4-44) and turning the adjusting screws. The holes in the cover are serrated to act as retainers to prevent the screws from turning after the adjustment is made.

To make a low-idle speed adjustment, put the engine speed control lever in the low-idle position. Turn the low-idle screw clockwise to decrease the speed or counterclockwise to increase the speed. The engine rpm can be


UPPER BEARING
COVER
CRANK
SLIDE BAR
RETAINER
GOVERNOR SPRING
THRUST BEARING
GOVERNOR WEIGHTS
TUBE

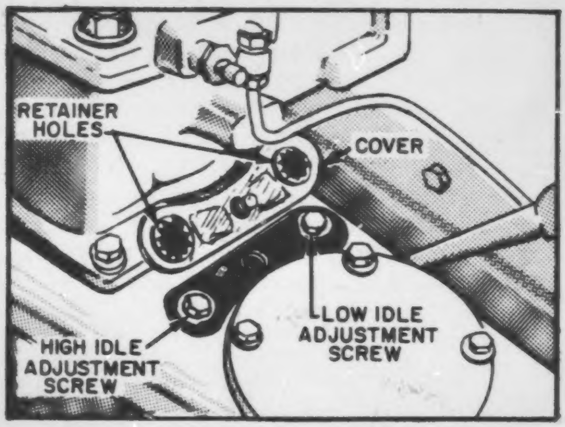
2.64X

Figure 4-43.—Cross section of a Caterpillar governor.

checked with a tachometer at the drive connection on the hour meter.

In checking engine speed at the hour meter, remember that the tachometer drive shaft turns only at one-half engine speed. If, for example, a 450 rpm idling speed is desired, you should read 225 rpm on the hand tachometer.

In ADJUSTING THE HIGH-IDLE SPEED at the governor, see that the engine speed control lever is pulled all the way back when you check the engine speed. The adjustment should be as close as possible to the manufacturer's recommendations. For example, if the recommended high-idle speed is given as 1550 rpm, and you read 1280 rpm (640 rpm x 2) at the tachometer drive connection, the engine is running too slowly to develop its rated power with a full load. In this case, turn the high-idle speed adjusting screw counterclockwise to increase the speed.


RETAINER HOLES
COVER
LOW IDLE ADJUSTMENT SCREW
HIGH IDLE ADJUSTMENT SCREW

2.65X

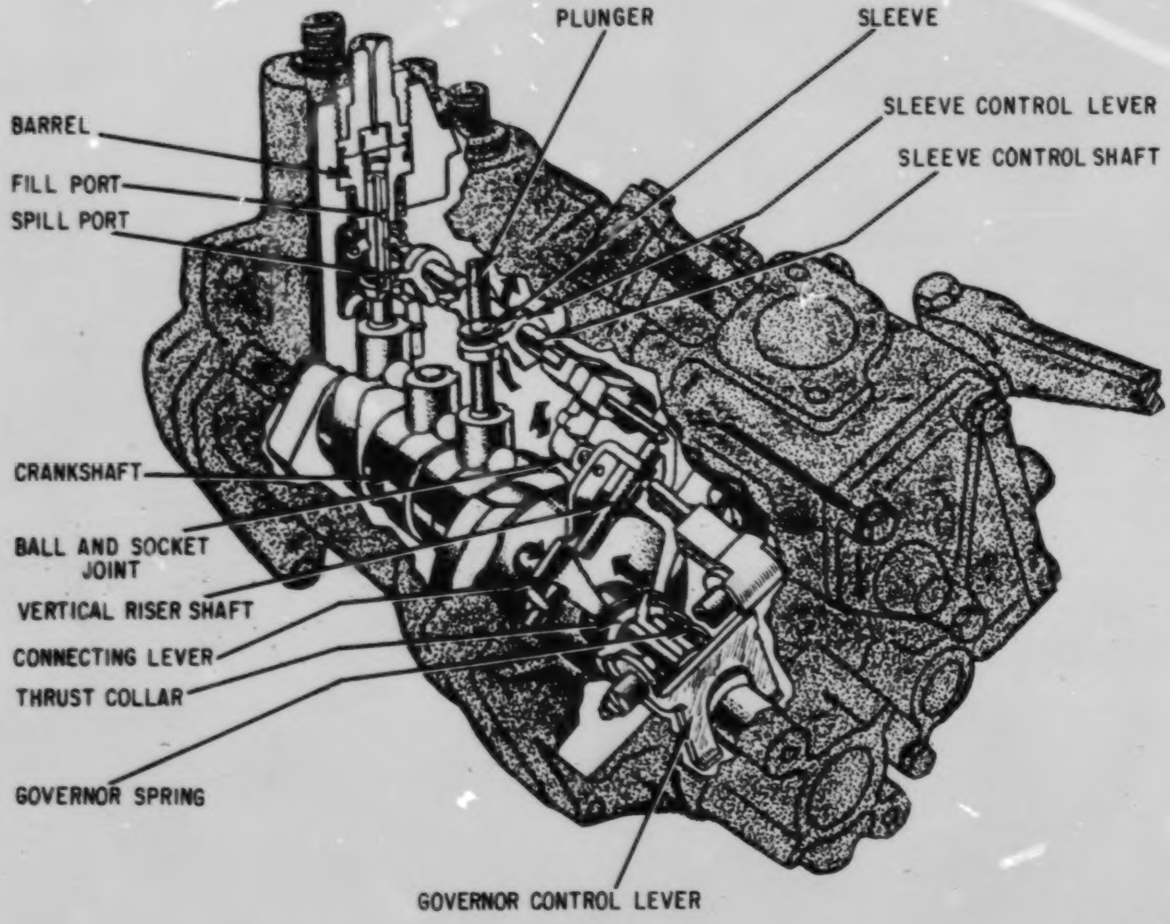
Figure 4-44.—Governor adjustments.

If the engine runs too fast, turn the same screw clockwise to reduce the speed. Make only small corrections at a time. After each adjustment, close and open the throttle and recheck the speed. A recommended maximum speed of 1550 rpm will result in approximately a full-load speed of 1400 rpm when the normal speed drop is considered. A full-load speed of 100 rpm less than recommended maximum without a load is good insurance against possible damage from overspeeding the engine.

If it is necessary to adjust full-load speed more accurately, special governor setting fixtures are needed. With them, the maximum full-load speed can be adjusted without actually loading the engine. If these governor setting fixtures are available, make sure you know how to use them, and follow the manufacturer's manual concerning the installation and use of the fixtures.

Sleeve Metering Fuel Pump

The injection pump used on small bore Caterpillar engines is referred to as a SLEEVE METERING fuel pump because of the method used to control the amount of fuel injected into the cylinders. The pump assembly (fig. 4-45) contains the fuel transfer pump, governor, and


PLUNGER
SLEEVE
BARREL
SLEEVE CONTROL LEVER
SLEEVE CONTROL SHAFT
FILL PORT
SPILL PORT
CRANKSHAFT
BALL AND SOCKET JOINT
VERTICAL RISER SHAFT
CONNECTING LEVER
THRUST COLLAR
GOVERNOR SPRING
GOVERNOR CONTROL LEVER

81.514

Figure 4-45.—Sleeve metering fuel pump assembly.

high pressure pump units in one housing. The entire fuel pump assembly is lubricated by diesel fuel and pressurized by the fuel transfer pump.

Rather than rotate the plungers to control the amount of fuel to be injected, like most pump and nozzle injection systems, the use of a sliding sleeve is incorporated with the plunger. The sleeve blocks a spill port, which is drilled into the plunger. The amount of plunger travel with its port blocked determines the amount of fuel to be injected

Whenever the fill port is below the bottom edge of the barrel, fuel under pressure from the housing is forced into the plunger, keeping a maximum supply of fuel available for injection when needed by the engine.

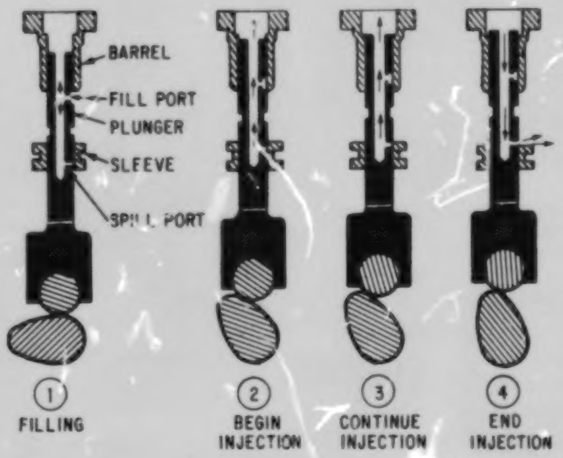
As the cam lobe raises the plunger (fig. 4-46), the fill port and spill port are blocked. When this occurs, the continued upward motion of the plunger pressurizes the trapped fuel and injection begins. Injection stops when the spill port, in the plunger, rises above the sleeve releasing the pressure within the plunger and barrel. The design of this pump allows maximum fuel when starting regardless of the throttle setting. The governor assumes control at idle speed, approximately 500 rpm, and controls the amount of fuel injected at all engine operating speeds. The only adjustment needed with this unit is the initial setting of the high and low idle speeds. The high pressure pumps are interchangeable for all engine models, with the plunger, barrel, and sleeve being replaced as a unit.

INTERNATIONAL HARVESTER FUEL INJECTION SYSTEMS

International Harvester engines that you may encounter have two types of fuel injection systems. The smaller engines use the Roosa Master fuel injection pump while the larger 817 series engines are equipped with a variation of the pump and nozzle system.

Roosa Master Fuel Injection Pump

The Roosa Master fuel injection pump commonly encountered is the opposed plunger, inlet metering, twin cylinder (DC), distributor type pump. The main components are the drive shaft, distributor rotor, transfer pump, pumping plungers, internal cam ring, hydraulic head, end plate, governor and the pump housing with an integral advance mechanism. Early advance mechanisms were attached to the pump housing and could be removed from the housing as a unit for servicing.



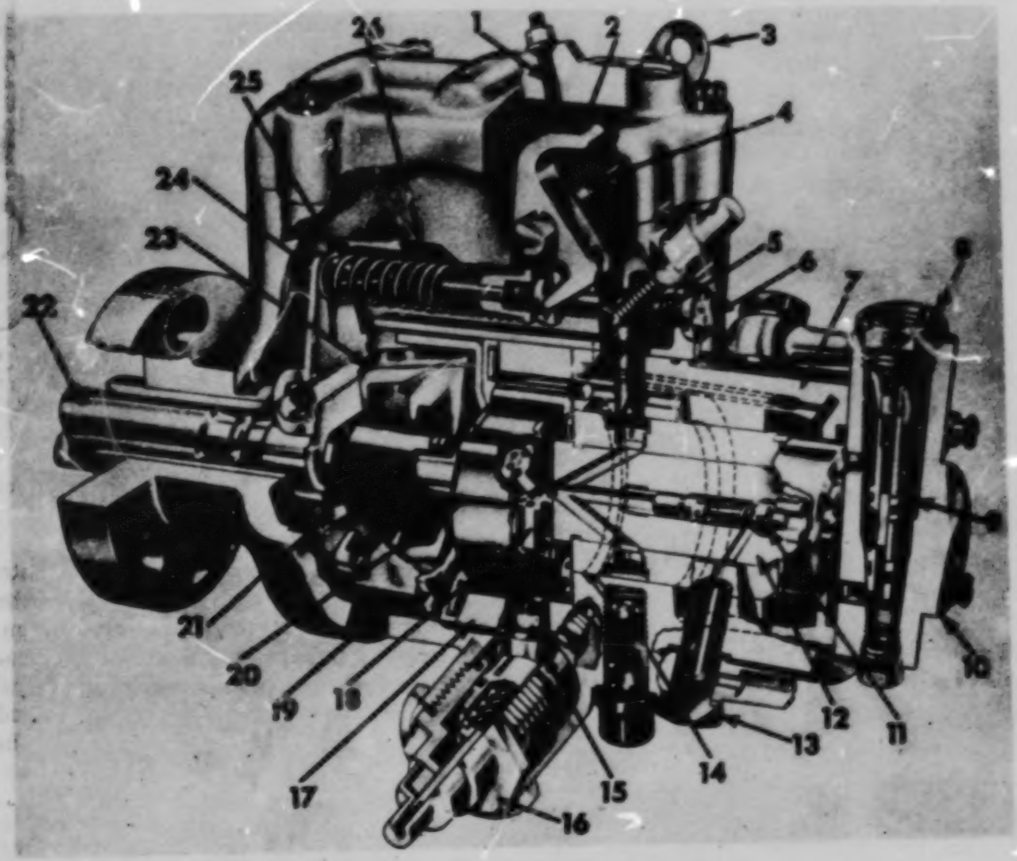
81.515

Figure 4-46.—Injection pump operating cycle.

The rotating members which revolve on a common axis, include the drive shaft, distributor rotor and transfer pump.

In the DC pump (fig. 4-47) the driving member is the drive shaft (22) that rotates inside a pilot tube pressed into the housing. The splines at the rear end of the shaft engage the internal splines in the front of the rotor (12) and turn the rotor with the shaft. A lip type seal prevents the entrance of engine oil into the pump and another retains the fuel used for pump lubrication. The governor weight retainer (19) is supported on the forward end of the rotor (12) that is externally splined.

The rotor contains the four pumping plungers (18), two in each of the two pumping cylinders. Slots in the rear end of the rotor provide a place for the two spring-loaded transfer pump blades (fig. 4-48). These blades



1. Idle adjusting screw.
2. Throttle shaft lever.
3. Shut-off arm.
4. Stop cam.
5. Metering valve.
6. Guide stud.
7. Hydraulic head.
8. Fuel inlet.
9. Pressure regulating valve assembly.
10. End plate.
11. Delivery valve stop.
12. Rotor.
13. Connector screw.
14. Ball check.
15. Cam advance pin.
16. Advance mechanism.
17. Cam ring.
18. Plungers.
19. Governor weight retainer.
20. Leaf spring.
21. Sleeve.
22. Drive shaft.
23. Governor weight.
24. Governor arm.
25. Governor spring.
26. Linkage hook.

81.350

Figure 4-47.—Cutaway view of Roosa Master fuel injection pump (model DC).

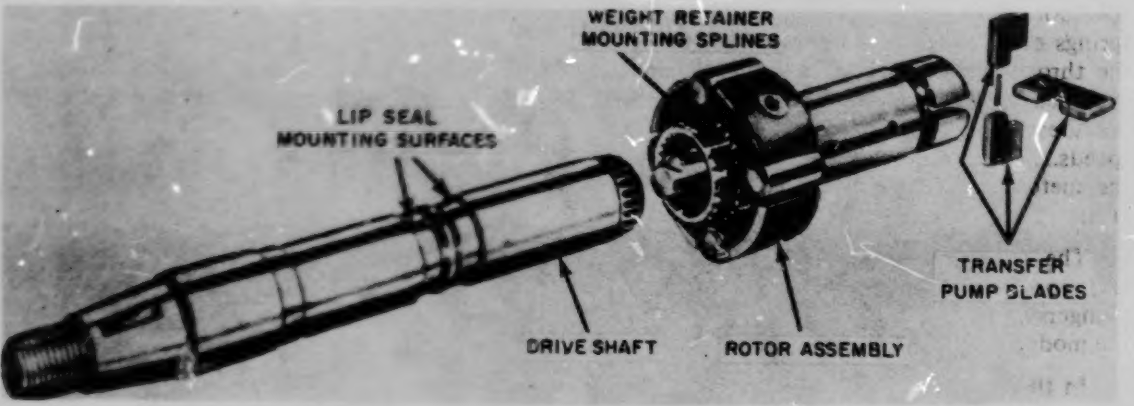

WEIGHT RETAINER MOUNTING SPLINES
LIP SEAL MOUNTING SURFACES
TRANSFER PUMP BLADES
DRIVE SHAFT
ROTOR ASSEMBLY

Figure 4-48.—Pump rotating parts (model DC). 81.351

turn inside a pump liner and develop the necessary pressure to charge the pumping cylinders.

The mechanical flyweight variable speed type **GOVERNOR** (fig. 4-49) is mounted on the drive end of the distributor rotor. The action of the weights in their retainer is transmitted through a sleeve to the governor arm, and through a linkage to the metering valve. The governed engine speed is the speed at which the

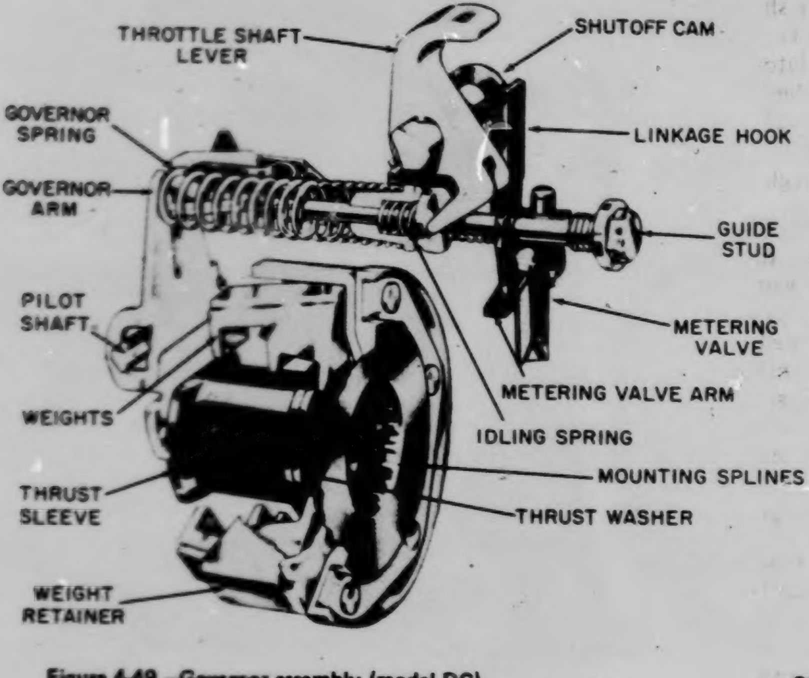

THROTTLE SHAFT LEVER
SHUTOFF CAM
GOVERNOR SPRING
LINKAGE HOOK
GOVERNOR ARM
GUIDE STUD
PILOT SHAFT
METERING VALVE
METERING VALVE ARM
WEIGHTS
IDLING SPRING
MOUNTING SPLINES
THRUST SLEEVE
THRUST WASHER
WEIGHT RETAINER

Figure 4-49.—Governor assembly (model DC). 81.352

112

force of the governor springs is balanced on the governor arm pivot shaft. The pressure of the springs on the governor arm can be varied with the throttle shaft lever, thus providing variable governed engine speed. The idling spring provides sensitive governor action at low engine speeds. A governor linkage hook, connected to the metering valve, is actuated by the governor arm.

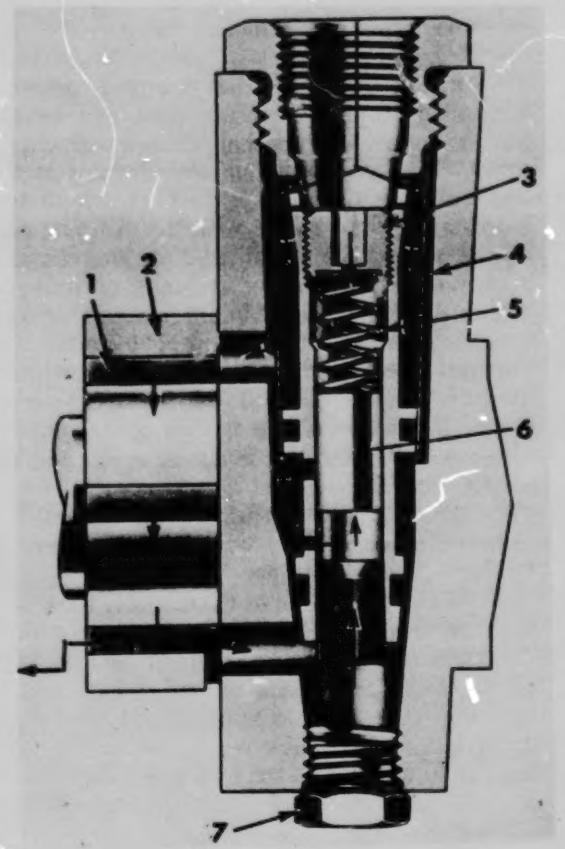
The drive end of the model DC rotor has two bores containing two plungers each. (The plungers are actuated in the same manner as for the model DB rotor.)

In the DC ROTOR, the shoe, which provides a large bearing surface for the roller, is carried in guide slots in the distributor rotor. The rotor shaft rotates with a very close fit in the hydraulic head. A passage through the center of the rotor shaft connects the pumping cylinder with one charging port and one discharge port. The hydraulic head in which the rotor shaft turns has six charging ports and six discharge ports.

A positive displacement, vane type fuel TRANSFER PUMP is mounted at the end of the rotor shaft. Fuel pressure developed by the fuel transfer pump is controlled by a pressure regulator valve in the pump end plate. A passage at the top of the transfer pump facilitates removal of air introduced in the system. This passage connects with the pump housing through the fuel return line to the supply tank.

Fuel is drawn from the final filter into the pump through the inlet strainer (4, fig. 4-50) by the vane type fuel transfer pump. The fuel transfer pump capacity greatly exceeds the fuel required for injection; therefore, a large percentage of the fuel from the pump is bypassed through the pressure regulating valve to the inlet side of the pump. The quanity of fuel bypassed increases as the pump speed increases. The bypass pressure also increases with speed.

Fuel not bypassed by the regulating valve passes through a hydraulic head passage to the metering valve. Fuel is metered by the metering valve in a quantity determined by engine demand.



1. Transfer pump blade.
2. Transfer pump liner.
3. End plate adjusting plug.
4. Inlet strainer.
5. Regulating spring.
6. Regulating piston.
7. End plate plug.

81.353

Figure 4-50.–Transfer pump (model DC).

As the rotor revolves, its charging port registers with one of six charging ports in the head. This rotor charging port connects perfectly to the pumping cylinder and axial passage of the rotor.

As the fuel enters the pumping cylinder, the plungers are forced outward, a distance proportionate to the quantity of fuel to be injected. The quantity of fuel entering the pumping cylinder is controlled by the fuel pressure at the charging ports, time available for charging, and total plunger displacement available as limited by the leaf spring.

Fuel pressure at the charging ports is controlled by the metering valve and by the transfer pump pressure which varies with engine speed. The time available for charging is the length of time the charging port in the hydraulic head remains in register with the charging port of the rotor. The length of time the charging port remains in register depends entirely on engine speed. The maximum amount of fuel which can be injected is limited by maximum outward travel of the plungers. This maximum plunger travel is limited by the roller shoes contacting the adjustable leaf spring stop. At the time when the charging ports are in register, the rollers are between the cam lobes (fig. 4-51); therefore, their outward movement is unrestricted during the charging cycle except as limited by the leaf spring.

The fuel is trapped in the cylinder for a very slight interval of time after charging is complete. This is caused by the fact that the charging port of the rotor has passed out of register with a charging port and the head and the rotor discharge port has not yet come into register with an outlet port of the hydraulic head.

Further rotation of the rotor brings its discharge port into register with an outlet passage in the hydraulic head, at which time the rollers simultaneously contact the opposing cam lobes. The cam lobes force the plungers toward each other, discharging the fuel from the cylinder through the outlet port into the outlet passage in the hydraulic head and the fuel injection line connected to this passage (fig. 4-52). The cam is relieved to allow a slight outward movement of the roller before the discharge port is closed off. This action drops the pressure in the injection line enough to give sharp cutoff injection and prevent nozzle dribbling.

A displacement type DELIVERY VALVE (fig. 4-52) is located in the drive passage of the rotor between the charging port and the discharge port of the rotor. It remains closed during charging and opens under high pressure as the plungers are forced together. Its purpose is to aid, by injection line pressure relief, the cam "retraction" previously described. Two small grooves are located on either side of the charging port of the rotor near its flange end. These grooves carry off fuel from the hydraulic head charging ports to the housing. This flow of fuel lubricates the cam, rollers, governor parts, etc. The fuel flows through the entire pump housing,

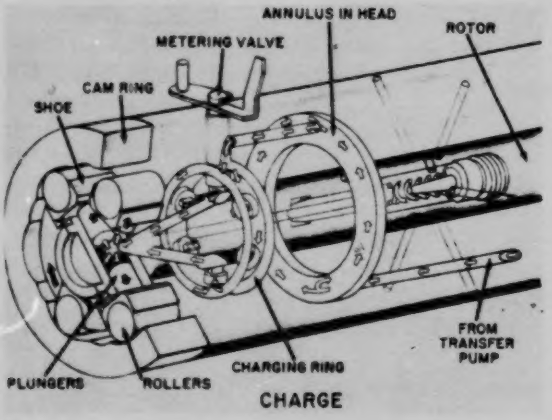


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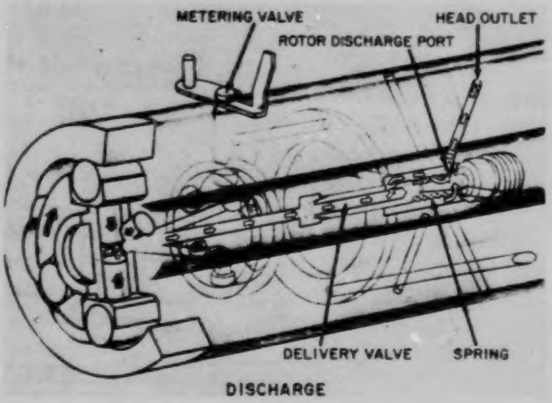
Figure 4-51.—Rotor in charging position with the rollers between the cam lobes (DC pump).



81.357

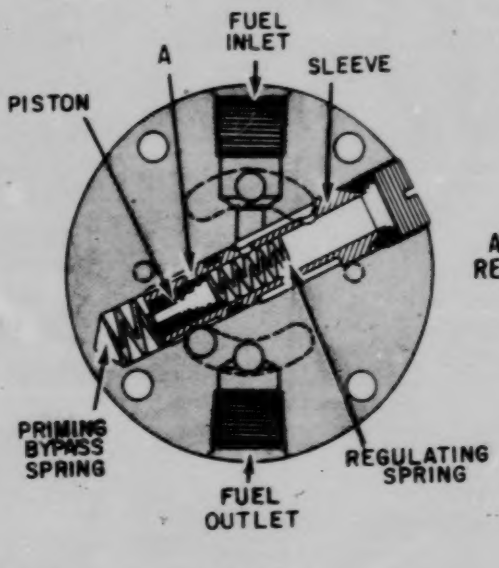
Figure 4-52.—Rotor in discharge position (DC pump).

absorbs heat, and is allowed to return to the supply tank through a fuel return line connected to the pump housing cover, thus providing for pump cooling.

The END PLATE functions to provide passages for fuel and to cover and absorb end thrust of the transfer pump; to house the pressure regulator valve; and to house the priming bypass spring which permits fuel to bypass the transfer pump during hand priming.

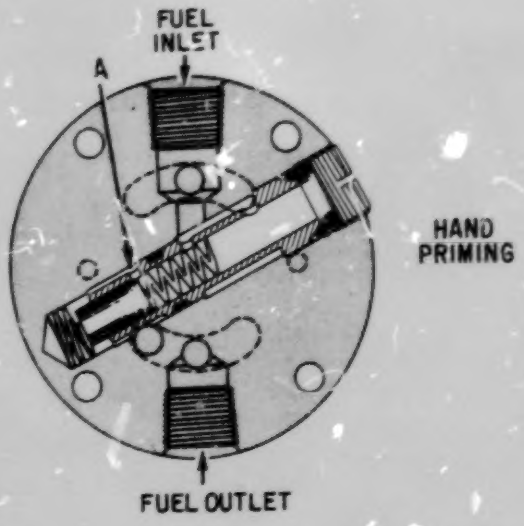
Figures 4-53, 4-54, and 4-55 show the regulating piston in three positions: at rest, during hand priming, and in operation. Figure 4-53 shows the piston covering the hand priming port (A) and resting against the priming bypass spring. During hand priming, the pressure differential across the transfer pump, caused by the hand primer, forces the piston down, compressing the spring until the priming port (A, fig. 4-54) is uncovered. Fuel bypasses the stationary transfer pump to fill the system.

When the piston is in the pressure regulating position, fuel forces the piston up the sleeve until the regulating port or ports (B, fig. 4-55) are uncovered. Since the pressure on the piston is opposed by the regulating spring the delivery pressure of the transfer pump is controlled by the spring rate, size, and number of regulating ports.


FUEL INLET
A
SLEEVE
PISTON
AT REST
PRIMING BYPASS SPRING
REGULATING SPRING
FUEL OUTLET

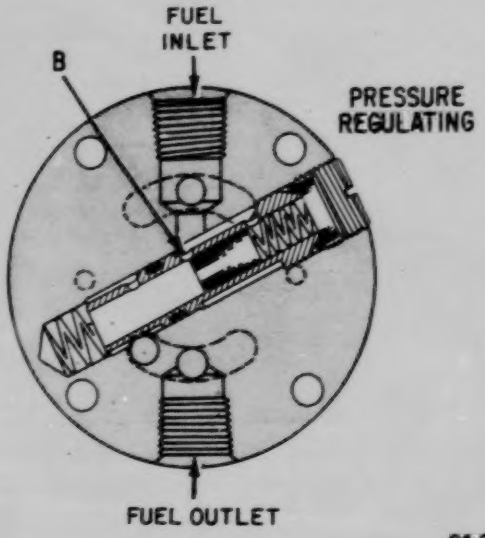
81.359

Figure 4-53.—Regulating piston, at rest.


FUEL INLET
A
HAND PRIMING
FUEL OUTLET

81.360

Figure 4-54.—Regulating piston, during hand priming.


FUEL INLET
B
PRESSURE REGULATING
FUEL OUTLET

81.361

Figure 4-55.—Regulating piston, in pressure regulating position.

The torque delivered by an engine increases progressively with a decreasing rpm caused by an overload. The torque continues to increase until it reaches its peak at a certain predetermined engine speed. This desirable engine feature is called TORQUE BACKUP. The torque backup, when the engine is overloaded, is caused primarily by the following three factors:

1. More time is available for combustion of fuel.
2. Volumetric efficiency increases as engine speed decreases.
3. Engine friction losses (and accessory loads) decrease with engine speed.

Since volumetric efficiency increases with decreasing engine speed, more fuel can be injected and burned at the reduced engine speed, thus increasing the torque output.

In order to fully explain how torque control is accomplished when the pump is properly adjusted, it is necessary to use an example, starting with a condition where the engine is operating at high idle speed and then progressively load the engine until engine rpm drops to peak torque speed.

When the engine is operating at high idle speed, no load, the quantity of fuel delivered is controlled by governor action on the metering valve. Torque screw and leaf spring adjustment have no effect under this condition.

As load is progressively applied, the governor action on the metering valve continues to control the quantity of fuel delivered until engine rpm drops to rated load speed. At this point, the governor has opened the metering valve enough to bring an arm on the valve into contact with the torque screw which prevents further opening of the metering valve. The maximum amount of fuel which can be injected at rated load speed is controlled by the torque screw; leaf spring adjustment has no effect.

As overload is progressively applied to the engine, the governor continues to hold the metering valve arm in contact with the torque screw; therefore, the metering valve does not move during overload operation. However, fuel delivery increases as the engine speed drops, due to the fact that the charging ports remain in register for a greater length of time because of slower engine speeds. This allows more time for the charge of fuel to pass through the metering valve which is stationary, thus charging the cylinder with a larger quantity of fuel.

As the engine speed continues to drop and reaches a speed at which maximum torque is developed, the charge of fuel becomes great enough to force the plungers outward far enough during each charging cycle to bring the roller shoes into contact with the leaf spring. This prevents further outward movement of the plungers and therefore limits the maximum amount of fuel which can be injected. From this it can be seen that the maximum amount of fuel which can be injected during overload operation below peak torque is controlled by the leaf spring adjustment.

In the DC pump, the speed advance mechanism provides controlled movement of the cam in the pump housing to advance injection at high speeds. The rising fuel pressure from the transfer pump increases flow to the power side of the advance piston (fig. 4-56). This flow from the transfer pump passes through a cut on the metering valve, through a passage in the hydraulic head, and then by the check valve in the drilled bottom head locking screw. The

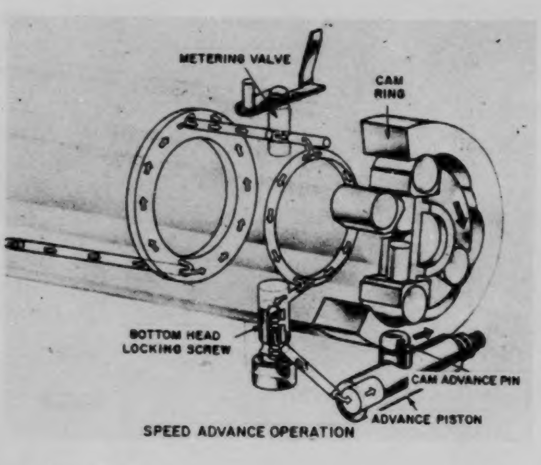


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Figure 4-56.—Fuel flow in speed advance operation.

check valve provides a hydraulic lock, preventing the cam from retarding during injection. Fuel is directed by a passage in the advance housing end plug to the pressure side of the advance piston. The piston moves the cam counterclockwise (opposite to the direction of pump rotation). The spring-loaded side of the piston balances the force of the power side of the piston and limits the maximum movement of the cam. Therefore, with increasing speed, the cam is advanced and, with decreasing speed, it is retarded.

Fuel Injector-
817 Series

The International 817 series engines use a "C"-type fuel injection pump that meters fuel to the injectors (fig. 4-57) in quantities proportional to load demands. This engine uses an open-type combustion chamber with a moderate swirling air motion. The function of the injector is to break up the fuel charge from the metering pump into finely atomized particles and to mix them with the available air.

The high pressure needed for good atomization and dispersion of the fuel is obtained mechanically from the downstroke of the cam-actuated plunger. This action confines the fuel into the small space below the plunger, within the bushing and injector tip. Here the fuel charge is then broken up and distributed to the combustion air as it passes through the multiorifice injector tip. Pressure is maintained through the entire downstroke of the plunger and a sharp cutoff of the spray is obtained when the plunger bottoms in the injector tip at the end of the stroke. This completes the cycle and another injection cycle starts with the engine intake stroke, when the plunger begins its "spring returned" upstroke, drawing clean air into the injector tip through the orifice holes. The fuel port in the bushing begins to uncover as the engine starts the compression stroke and shortly afterwards the metering pump begins to deliver the metered fuel to the injector.

The metered fuel passes through the inlet screen, the check valve, and the port in the bushing; then it mixes with the air in the injector tip. As the engine approaches top dead center of the compression stroke, the cam drives the plunger rapidly down to inject the trapped charge of fuel and air below the plunger into the combustion chamber. The fuel port in the bushing is closed off early in the downstroke, protecting the check valve and fuel passage from the high injection pressure.

The injector plunger remains firmly bottomed during the power stroke and exhaust stroke of the engine, preventing backflow of combustion products into the injector. This injector has a variable beginning and a constant ending of injection due to the volume of the fuel supplied at different speed ranges, thereby

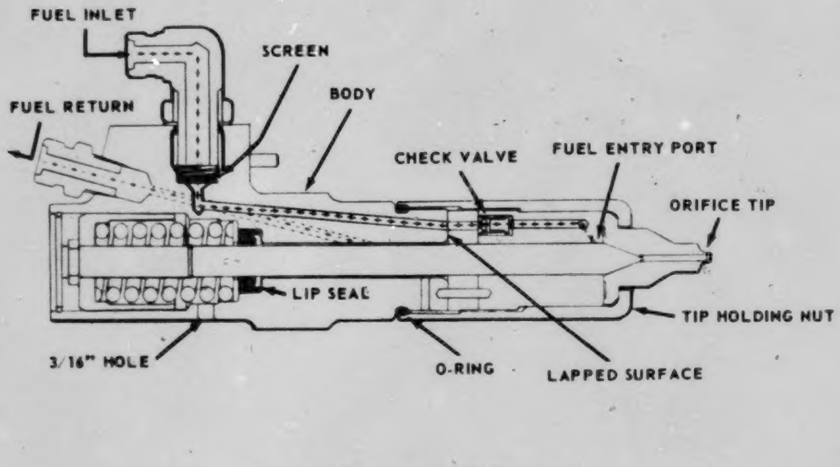


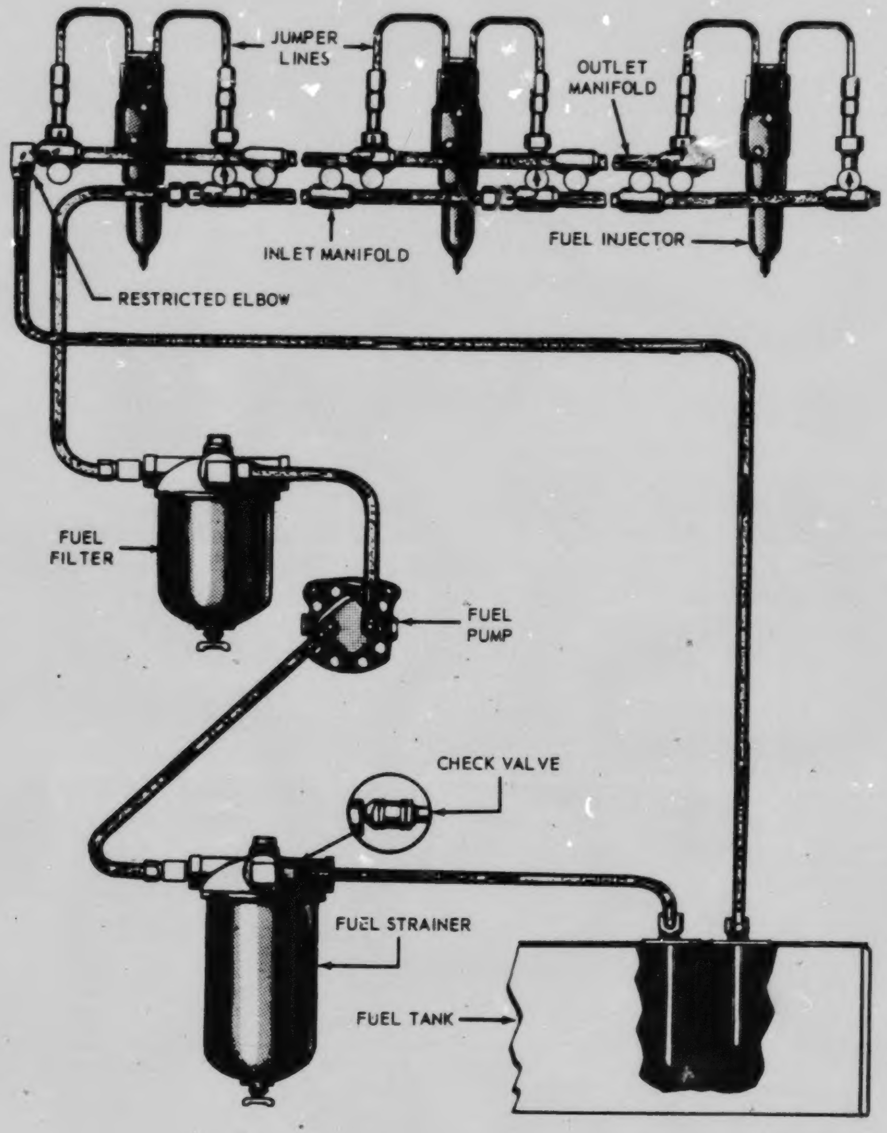
Figure 4-57.—Injector (817 engine).

varying the distance the plunger must travel before contacting the fuel.

GENERAL MOTORS UNIT INJECTION

The General Motors diesel uses the unit injection system, combining the pump and the nozzle in one housing. There is one unit injector per cylinder. (See fig. 4-58.)

The fuel first passes through a primary filter located between the fuel tank and the transfer pump, which may be of either the gear or the vane type. On the discharge side of this pump is


JUMPER LINES
OUTLET MANIFOLD
INLET MANIFOLD
FUEL INJECTOR
RESTRICTED ELBOW
FUEL FILTER
FUEL PUMP
CHECK VALVE
FUEL STRAINER
FUEL TANK

2.67X

Figure 4-58.—Diagram of typical General Motors diesel fuel system.

a secondary filter with a drain cock at the bottom of the housing for removing water and dirt separated from the fuel. From the filter the fuel passes to the fuel manifolds. The LOWER MANIFOLD is the INLET, from which the fuel flows into the injector.

Each injector is fitted into a water-cooled copper tube in the cylinder head and is held in place by an injector clamp. It is operated by a push rod and rocker arm. As the rocker arm forces the plunger down, the upper helix closes the upper port, and fuel injection begins. The upper helix and a lower helix are machined into the lower end of the plunger for metering purposes. The relation of these helices to the ports changes with the rotation of the plunger. As the plunger moves downward, a portion of the fuel oil trapped in the bushing under the plunger is displaced through the lower port back into the supply chamber, until the port is closed off by the lower end of the plunger. A portion of the fuel still trapped under the plunger is then forced upward through the central passage of the plunger into the recess between the two helices and then into the supply chamber through the upper port, until the upper helix closes that port. With the upper and lower ports closed, the remaining fuel trapped under the plunger is subjected to increased pressure by the continued downward movement of the plunger. When sufficient pressure is built up, the injector valve is lifted off its seat and the fuel is forced through small orifices in the spray tip and atomized into the combustion chamber. The rotation of the plunger, by moving the rack, changes the position of the helices and retards or advances the closing of the ports and the beginning and ending of the injection period. Fuel injection ends when the lower helix opens the lower port. The remaining fuel then proceeds through the UPPER MANIFOLD, or OUTLET, back into the tank.

Injector Timing

Whenever an injector has been removed and reinstalled, or a new injector has been installed in an engine, the injector must be timed and the injector control rack positioned.

In timing injectors on General Motors series 71 diesel engines, use the proper timing gage (fig. 4-59).

To properly time an injector, adjust the injector follower to a definite height in relation to the injector body. (See fig. 4-60.) This will vary according to the size of the injector being used. Check the manufacturer's manual to determine the proper gage to use.

Place the engine speed control lever to the shutoff position and rotate the crankshaft in the direction of engine rotation until the exhaust valves are fully depressed on the particular cylinder to be timed. Place the small end of the injector timing gage in the hole provided in the top of the injector body. Loosen the push rod locknut, turn the push rod and adjust the injector rocker arm until the extended part or shoulder of the gage will just pass over the top of the injector follower. Hold the push rod and tighten the locknut. Check adjustment after tightening the locknut and readjust as necessary. By following the sequence of the engine firing order, you can time the injectors in one revolution of the crankshaft.

Equalizing Injectors

Equalizing injectors means to adjust the injector racks so that all injectors in an engine

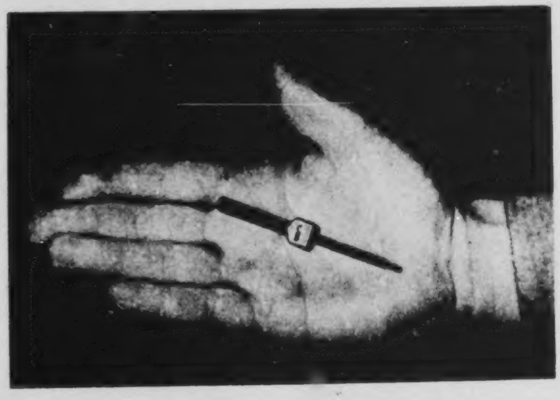


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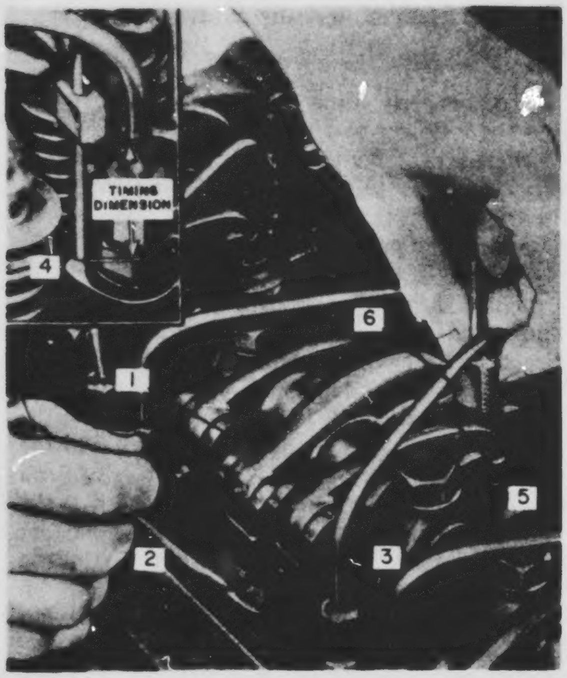
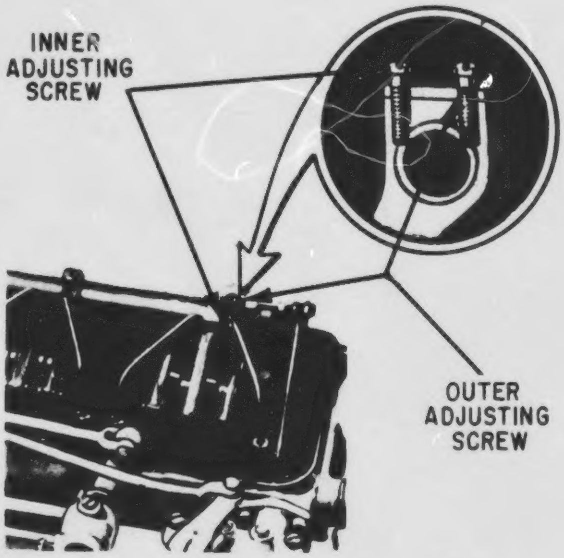
Figure 4-59.–Timing gage.



1. Rocker injector arm.
2. Push rod.
3. Lock nut.
4. Fuel injector.
5. Injector follower.
6. Injector timing gage.

81.365

Figure 4-60.—Timing fuel injectors.



2.169

Figure 4-61.—Control rack adjusting screw.

inject the same amount of fuel at any given engine speed. This is done by adjusting the inner and outer adjusting screw on the rack control lever. (See fig. 4-61.) This is a rather delicate adjustment to make.

When calibrated injectors are used, the manufacturer's method of equalizing racks should be followed.

It may be necessary to make these adjustments several times before the engine runs just right.

Sometimes smoother engine operation can be obtained by making slight changes to the equalizing adjustments after the engine is warmed to operating temperatures (above 140°F). For example, one cylinder may not be carrying its share of the load as indicated by a comparatively cooler cylinder. Its control rack, therefore, should be adjusted for more fuel. A slight knocking noise from another cylinder would indicate an adjustment for a slightly smaller amount of fuel.

To increase the amount of fuel injected, loosen the outer adjusting screw and tighten the inner screw, thereby moving the control rack inward. To decrease fuel injection, loosen the inner adjusting screw slightly and tighten the outer screw which moves the control rack outward. In making these operating adjustments, never turn the adjusting screws more than one-fourth turn at a time, for if one injector is adjusted too far out of line with the others, it will prevent the full travel of the racks and reduce the maximum power of the engine.

Do not attempt to obtain a smooth running engine by changing control-rack settings without first timing and equalizing injection in the recommended manner.

Governor

Horsepower requirements for an engine may vary because of fluctuating loads; therefore, some method must be provided to control the amount of fuel required to hold the engine speed reasonably constant during load fluctuations. To accomplish this control, a governor is introduced in the linkage between the engine speed control and the fuel injectors. On the GM series 71 engines the governor is mounted on the front end of the blower and is driven by the upper blower rotor.

There are three types of governors commonly used on 3-, 4-, and 6-cylinder GM series 71 engines. They are:

1. Limiting speed mechanical governor
2. Variable speed mechanical governor
3. Hydraulic governor

Engines requiring a minimum and maximum speed control, together with manually controlled intermediate speeds, are equipped with a LIMITING SPEED MECHANICAL GOVERNOR.

Engines subject to varying load conditions require a governor to maintain a near constant engine speed. A VARIABLE SPEED MECHANICAL GOVERNOR usually suffices for this purpose. This type of governor has an engine speed control lever, which the operator can use to change the speed manually.

A HYDRAULIC GOVERNOR is more effective than a mechanical governor in maintaining a constant engine speed with a minimum speed droop under varying load conditions. The speed droop is the difference between no-load maximum speed and full-load maximum speed.

Since GM series 71 engines are used for many different purposes, the type of governor must be chosen to suit the installation. The variable speed mechanical governor is the one commonly used on construction equipment.

The variable speed mechanical governor performs three functions: (1) controls the engine idle speed, (2) limits the maximum no-load speed, and (3) holds the engine at any constant speed between idle and maximum as desired by the operator.

Governor difficulties are usually indicated by speed variations of the engine; however, it does not necessarily mean that all speed variations are caused by the governor. Make sure the speed changes are not the result of excessive load fluctuations. Check the engine to be sure that all cylinders are firing properly. Check for bind that may exist in the governor operating mechanism or in the linkage between the governor and the injector control tube. After you are fairly certain that it is a governor malfunction that is causing the difficulties, proceed with governor adjustments as outlined in the manufacturer's manual for the particular installation with which you are working.

THE CUMMINS PRESSURE TIME (PT) FUEL SYSTEM

The PT fuel system is used exclusively on the Cummins diesel engine found in modern equipment.

The operation of the Cummins PT fuel system is based on the basic principle of hydraulics, that by changing the pressure of a liquid flowing through a pipe, you change the amount of liquid coming out of the open end. Decreasing the pressure decreases the flow or amount of liquid delivered, or vice versa.

Fuel Pump

The fuel pump is made up of three main units: (1) a gear pump which draws fuel from the supply tank and delivers it under pressure through the pump and supply lines to the individual injectors, (2) the pressure regulator which limits the pressure of the fuel to the injectors, and (3) the governor and throttle which act independently of the pressure regulator to control fuel pressure to the injectors. The location of these respective units of the pump are indicated in figure 4-62.

Governor

Mechanical governor action is provided by a system of springs and weights; the governor has

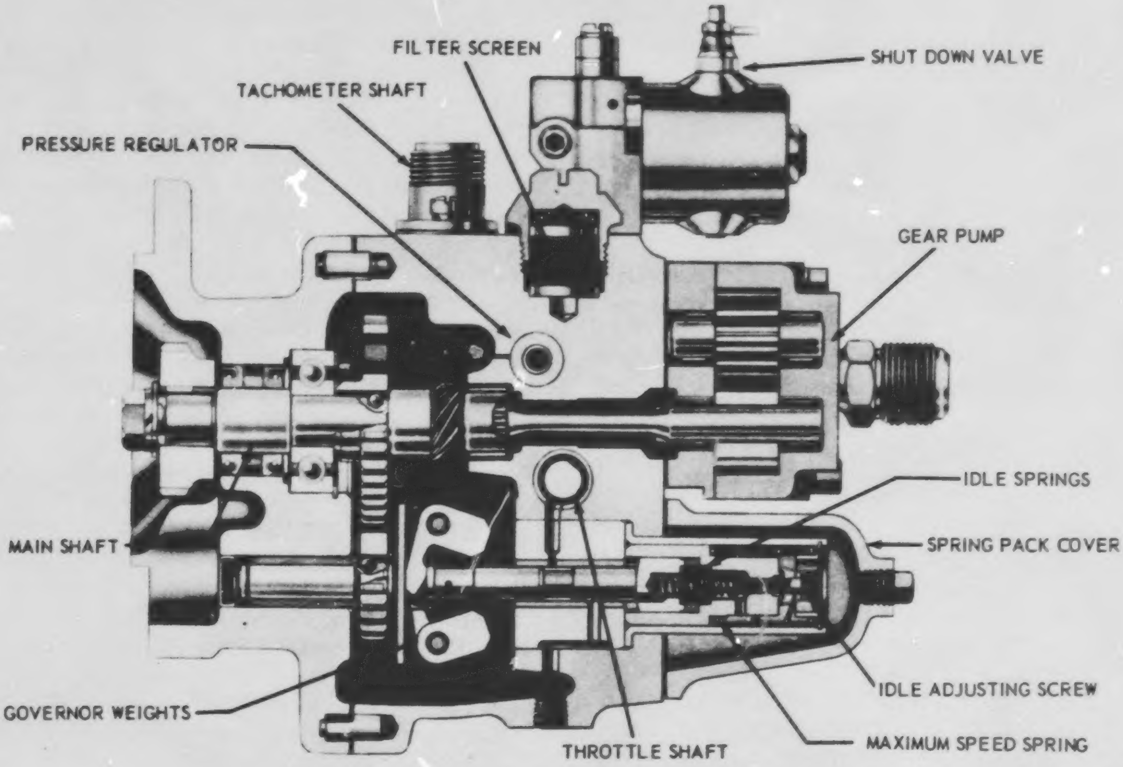

FILTER SCREEN
SHUT DOWN VALVE
TACHOMETER SHAFT
PRESSURE REGULATOR
GEAR PUMP
IDLE SPRINGS
MAIN SHAFT
SPRING PACK COVER
IDLE ADJUSTING SCREW
GOVERNOR WEIGHTS
THROTTLE SHAFT
MAXIMUM SPEED SPRING
2.72X

Figure 4-62.—Cross section of PT fuel pump.

two functions. First, it maintains sufficient fuel for idling with the throttle control in idle position; and second, it cuts off fuel above maximum rated rpm. The idle springs in the governor spring pack push on the governor plunger so that the idle fuel jet is opened enough to permit passage of fuel to maintain engine idle speed.

During operation between idle and maximum speeds, fuel flows through the governor to the injectors in accord with the engine requirements as controlled by the throttle and limited by the pressure regulator. When the engine reaches governed speed, the flyweights move the governor plunger, cutting off fuel passages to the fuel supply manifold. At the same time another passage opens and dumps the fuel to the supply manifold back into the main pump body. In this manner, engine speed is controlled and limited by the governor regardless of throttle position. Fuel leaving the governor travels through the shutdown valve, inlet supply lines, and on into the injectors.

Maximum engine speed is adjusted by removing or adding shims under the maximum speed spring. Normally, this adjustment is made at the time of overhaul and will not have to be changed in the field. To adjust the idle speed, the engine should first be warmed up to normal operating temperature. Remove the pipe plug from the end of the spring-pack cover and turn the idle adjusting screw IN TO INCREASE the speed, or OUT TO DECREASE the speed. Idle speed should be set 40 to 50 rpm lower than desired if the adjustment is made with the engine running. The reason is that air collects in the spring-pack housing and a speed change will result when the housing fills with fuel.

Two models of PT fuel pumps are used: the PT (type G) and PT (type R). The PT (type G) indicates that fuel pressure regulation is a part of the governor function. The PT (type R) refers to fuel pressure regulation as a function of a regulator assembly.

Injectors

The fuel injectors are operated mechanically by a plunger return spring and a rocker arm mechanism operating off the camshaft. Fuel circulates through the injector during the intake and compression strokes. From the inlet connection, fuel flows down the inlet passage of the injector, around the injector plunger, between the body end and cup, up the drain passage to the drain connections and manifold, and back to the supply tank. (See fig. 4-63.)

As the plunger comes up, the injector feed passage is opened and fuel flows through the metering orifice into the cup, at the same time fuel flows past the cup and out the drain orifice. The amount of fuel which enters the cup is controlled by the fuel pressure against the metering orifice.

The plunger during injection moves down until the metering orifice is closed and the fuel in the cup is injected into the cylinder. While the plunger is seated in the cup, all fuel flow in the injector is stopped.

Injector adjustments are very important on PT injectors because they perform the dual functions of metering and injecting. Check the manufacturer's manual for proper settings of injectors. On an engine where new or rebuilt injectors have been installed, initial injector adjustment can be made with the engine cold. Always readjust the injectors, using a torque wrench calibrated in inch-pounds, after the engine has been warmed up to where the oil temperature is between 140°F and 160°F.

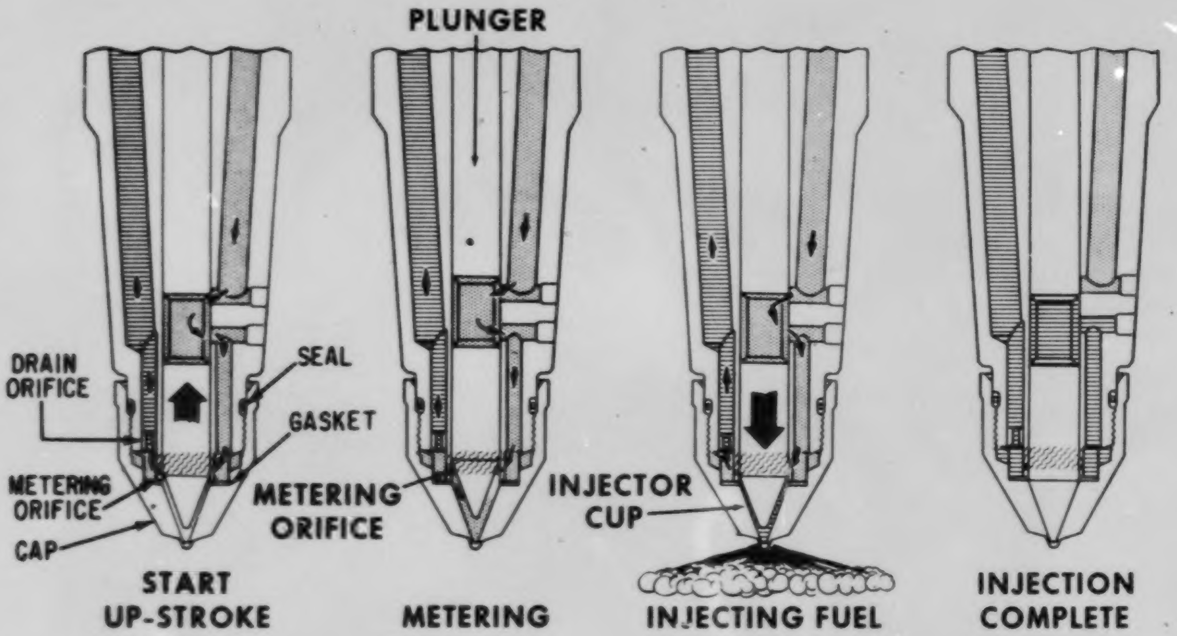


Figure 4-63.—Fuel injector cycle in a PT injector.

SUPERCHARGERS AND TURBOCHARGERS

Many late model diesel engines have a supercharger or turbocharger as part of the air system. These units force additional air into the combustion chambers so the engine can burn more fuel and develop more horsepower.

The use of a supercharger, such as the one illustrated in figure 4-64 will cause an increase in power developed by the engine on which it is used. The supercharger is similar to an air compressor in that it compresses the inlet air and actually forces the air into the cylinders when the intake valves open. This increased volume of air causes higher pressures and temperatures in the cylinders. In addition, the amount of fuel can be increased to maintain a fuel air ratio of approximately 15 to 1. As a result, the engine will develop more horsepower. Another advantage of using the supercharger is an increase in cylinder turbulence which allows more efficient mixing of the fuel with the air. This mixing results in more efficient burning and increased fuel economy.

Four-stroke engines are supercharged either by positive displacement rotary blowers or by centrifugal blowers. The positive displacement blowers are driven from the crankshaft, either by gears, chains, or belts. The centrifugal blowers are driven by turbines operated by exhaust gases coming from the engine which the blower serves.

A turbocharger utilizes normally wasted exhaust energy to increase the amount of air taken into an engine. A greater quantity of fuel may be efficiently used, and the result is an increase in horsepower. The turbocharger (fig. 4-65) consists of three basic parts: an exhaust

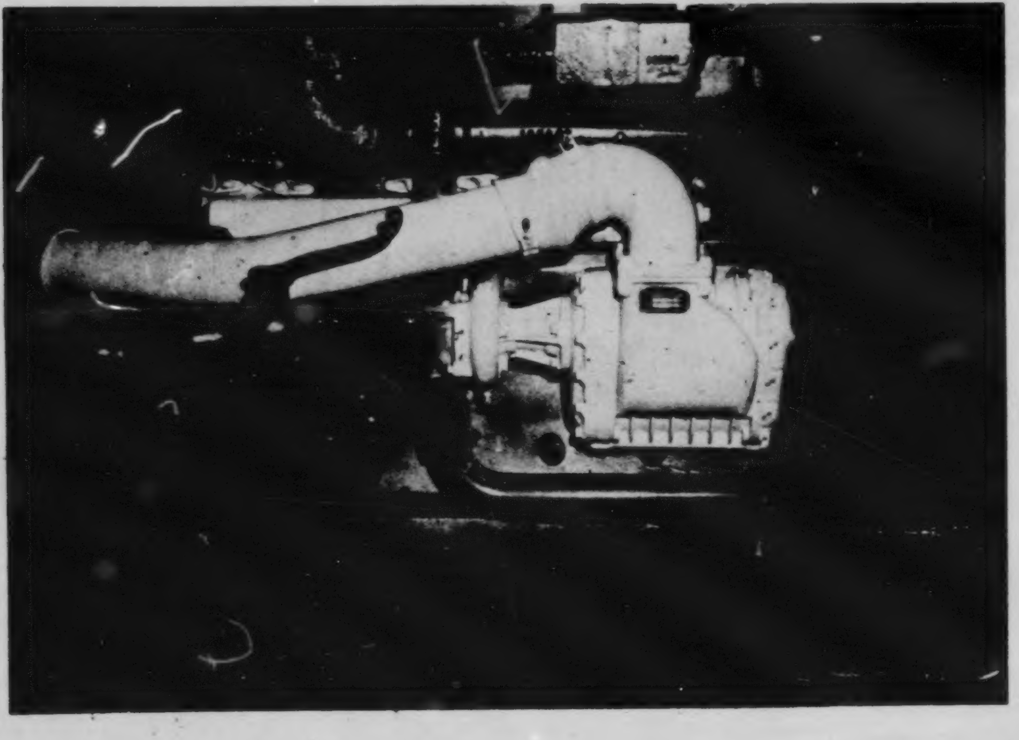


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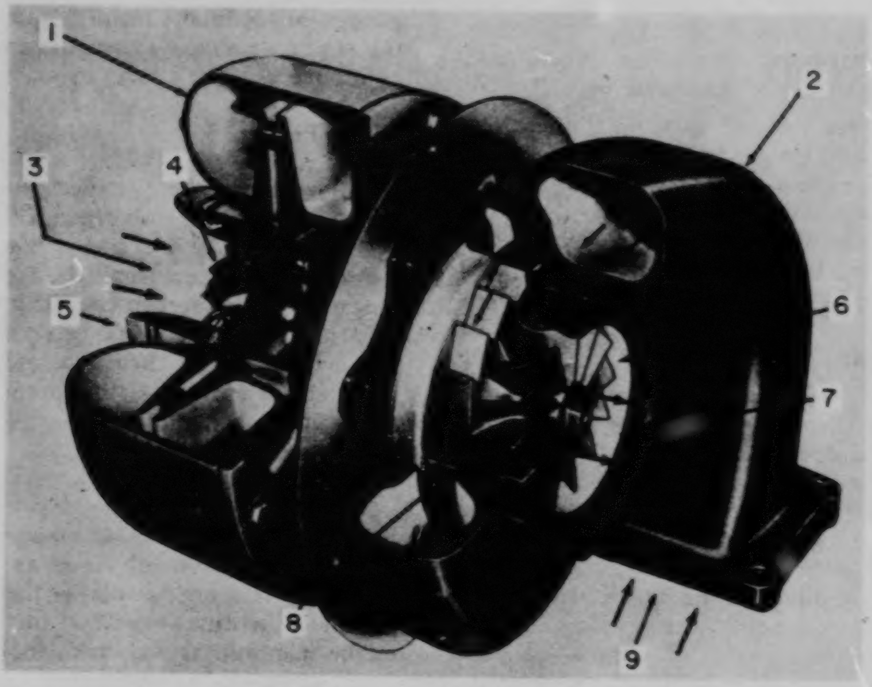
Figure 4-64.—Supercharger.



1. Compressor Cover
2. Turbine Housing
3. Air Inlet Opening
4. Impeller
5. Compressor Extension
6. Turbine Wheel
7. Exhaust Outlet
8. Nozzle
9. Exhaust Inlet Opening

81.367

Figure 4-65.–Turbocharger (cutaway view).

gas turbine, sometimes called the hot wheel; an impeller or compressor, referred to as a cold wheel; and housings which support the parts and direct the flow of exhaust gases and intake air. Exhaust gases passing through the turbine cause it and the compressor impeller to rotate. Air is therefore pumped into the engine and a greater amount is available than would be supplied by normal atmospheric pressure. Hence, more fuel can be burned efficiently, and engine power can be increased.

Exhaust gases enter the turbine housing and are directed through vanes of the nozzle toward the turbine blades. The exhaust gases provide the driving force to turn the turbine and are then expelled from the turbine housing at the outlet. Air from the air cleaner passes through the inlet opening of the compressor housing and the impeller. Air is compressed as it passes through the impeller and is then directed to the inlet manifold of the diesel engine.

The rotating assembly, consisting of the impeller, the turbine, and a common shaft, is the heart of the turbocharger. These parts are designed and built to operate at extremely high speeds; 50,000 revolutions per minute is often encountered in normal operation. At such high speeds, balance is of utmost importance. A very slight unbalance shows up at high speeds and can be detected by excessive vibration.

Labyrinth or screw-type seals are utilized on the large turbocharger. Piston ring type oil seals are used with small turbochargers.

To keep the lubricating oil in the unit and the hot exhaust gases out, air pressure is bled from the compressor housing to balance the normal oil pressure at the impeller seal and the exhaust pressure at the turbine seal. The rotating speed of the turbine changes as the energy level of the exhaust gas changes. Thus the engine is supplied with enough air to burn the fuel for its load requirements at all speeds.

Turbochargers and superchargers require little maintenance between engine overhauls if the air cleaners are serviced regularly, in accordance with the manufacturer's recommendations. The turbocharger turbine blades and nozzles require periodic cleaning to remove carbon deposits which cause an unbalanced condition at the high relative speeds at which the turbine must turn.

COLD WEATHER STARTING

Diesel fuel evaporates much slower than gasoline and requires more heat to cause combustion in the engine's cylinders. For this reason, preheating devices and starting aids are found on all Navy equipment using diesel engines. These devices and starting aids either heat the air before it is drawn into the cylinder or allow combustion at a lower temperature than during normal engine operation.

PREHEATERS

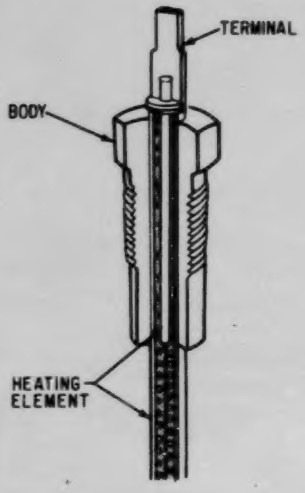
Preheaters, the most common type of heating device, are installed in the intake manifold or in the case of 2-stroke cycle engines, are placed in the air passages surrounding the cylinders. The preheater burns a small quantity of diesel fuel in the air prior to the air being drawn into the cylinders. This burning process is accomplished by the use of either a glow plug or an ignition coil which produces a spark to ignite a fine spray of diesel fuel. The resulting heat warms the remaining air before it is drawn into the cylinders. The Caterpillar diesel, equipped with a gasoline starting engine, passes the exhaust of the starting engine through an inner passage of the intake manifold. Here the heat of the starting engine's exhaust is absorbed by air before it enters the diesel's cylinders.

GLOW PLUGS

Glow plugs are installed directly in the precombustion or turbulence chamber of the cylinder head. The injection nozzle is also in this chamber. While you crank the engine, the glow plug (fig. 4-66) is turned on. The heat created by electrical resistance in the glow plug heats the fuel and air mixture. Heat generated by the glow plug permits burning of the fuel in the chamber and cylinder.

STARTING FLUID

Starting fluid, in either an aerosol container or capsule, is frequently used as a starting aid. This fluid is a highly volatile fluid (ether or a suitable substitute) which is injected into the intake manifold as you crank the diesel engine. Since ether has a low ignition point, the heat generated in the combustion chamber is able to ignite it. Heat from this ignition then ignites the



81.517

Figure 4-66.—Glow plug.

diesel fuel and normal combustion takes place. Once the diesel engine starts, no more fluid is needed.

When using cold weather starting aids, be sure to follow the manufacturer's instruction in order to prevent damage to the engine or the starting aid.

DIESEL FUEL SYSTEM MAINTENANCE

If all diesel engines had nearly identical fuel systems (like gasoline engines) trouble diagnosis and maintenance procedures could follow a general pattern much like the one that is used for gasoline engines. But, with the exception of similar fuel tanks, filters, and a basic piping system, diesel engine fuel systems differ considerably. Consequently, each engine manufacturer recommends different specific maintenance procedures. Those described herein for the more popular International, Caterpillar, Cummins, and General Motors diesels are by no means all you will need to know. However, the tune-up and maintenance procedures described are representative of jobs you will do. For all jobs you do not thoroughly understand, refer to the manufacturer's maintenance manual for the fuel system concerned.

DIRT IN FUEL SYSTEM

Many diesel engine operating troubles result directly or indirectly from dirt in the fuel system. That is why proper fuel storage and handling are so important. One of the most important aspects of diesel fuel is cleanliness. The fuel should not contain more than a trace of foreign substance; otherwise, fuel pump and injector troubles will occur. Diesel fuel, because it is more viscous than gasoline, will hold dirt in suspension for longer periods. Therefore every precaution should be made to keep the fuel clean.

If the engine starts missing, running irregularly, rapping, or puffing black smoke from the exhaust manifold, look for trouble at the spray nozzle valves. In this event, it is almost a sure bet that dirt is responsible for improper fuel injection into the cylinder. A valve held open or scratched by particles of dirt so that it cannot seat properly will allow fuel to pass into the exhaust without being completely burned, causing black smoke. Too much fuel may cause a cylinder to miss entirely. If dirt prevents the proper amount of fuel from entering the cylinders by restricting spray nozzle holes, the engine may skip, or stop entirely. In most cases, injector or spray valve troubles are easily identified.

Improper injection pump operation, however, is not so easily recognized. It is more likely caused by excessive wear than by an accumulation of dirt or carbon such as the spray nozzle is subjected to in the cylinder combustion chamber. If considerable abrasive dirt gets by the filters to increase (by wear) the very small clearance between the injector pump plunger and barrel, fuel will leak by the plunger instead of being forced into the injector nozzle in the cylinder. This gradual decrease in fuel delivery at the spray nozzle may remain unnoticed for some time, or until the Equipment Operator complains of sluggish engine performance.

Although worn injector pumps will result in loss of engine power and hard starting, worn piston rings, cylinder liners, and valves (air intake or exhaust) can be responsible for the same conditions. However, with worn cylinder parts or valves, the hard starting and loss of power will be accompanied by poor compression, a smoky exhaust, and excessive blowby from the crankcase breather.

WATER IN FUEL SYSTEM

It requires only a little WATER in a fuel system to cause an engine to miss, and if present in large enough quantities, the engine will stop entirely. Many fuel filters are designed to clog completely when exposed to water, thereby stopping all fuel flow. Water that enters a tank with the fuel oil, or that forms by condensation in a partially empty tank or line, usually settles to the lowest part of the fuel system. This water should be drained off daily.

AIR IN FUEL SYSTEM

Air trapped in diesel fuel systems is one of the main reasons for a hard starting engine. Air can enter the fuel system at loose joints in the piping or through a spray nozzle that does not close properly. Letting the vehicle run out of fuel will also cause air to enter the system. Like water, air can interfere with the unbroken flow of fuel from the tank to the cylinder. A great deal of air in a system will prevent fuel pumps from picking up fuel and pushing it through the piping systems. Air can be removed by bleeding the system as set forth in the procedures described in the manufacturer's maintenance manual.

SERVICING INJECTION EQUIPMENT

Diesel injection parts (injectors or spray valves and pumps) are assembled units of precision parts; they cannot be cleaned or adjusted adequately in the field. To operate efficiently, they must be cleaned, repaired, and adjusted with special equipment.

Proper arrangement and suitable housing of injector test apparatus are essential so that the apparatus can be given proper care and protection.

CLEANING INJECTORS

Unless special servicing equipment and repair instructions are available, defective nozzles and pumps are usually exchanged for new ones. However, in an emergency, and if spray valves or pumps are not too badly worn, they may be returned to a serviceable condition, with minor adjustment, after a thorough cleaning.

Injector spray nozzles or pumps should never be disassembled in the field. They should be removed from the equipment and brought to the shop for repair. The first requirement for the cleaning job is a clean working space.

Use clean diesel fuel for washing the parts. Disassemble one nozzle or pump assembly at a time to prevent mixing of mating parts. Exercise care to prevent damage to nozzle and pump parts. Inspect and clean all parts as they are disassembled. Carbon may be scraped from the outside of the nozzle, but be careful not to mar the edges of the holes (orifices). When cleaning fluid is used to clean pump and nozzle parts, dip the parts in diesel fuel immediatley after cleaning. This will prevent moisture from the hands from marring the highly polished surfaces.

Reaming tools and special drills are provided for cleaning spray nozzle holes. No drills other than those recommended by the manufacturer should be used. The drills are hand operated, the smaller, needle-type being held with a small chuck called a pin vise (fig. 4-67).

In performing reaming operations, remove only the foreign matter; be particularly careful not to burr the metal.

TESTING FUEL INJECTION NOZZLES

When fuel injection troubles are suspected, and before removing the injector nozzles for shop testing, it is a good practice to check the injectors to find out if just one of them is causing the trouble. To do so, first operate the engine at a speed at which the defect is more

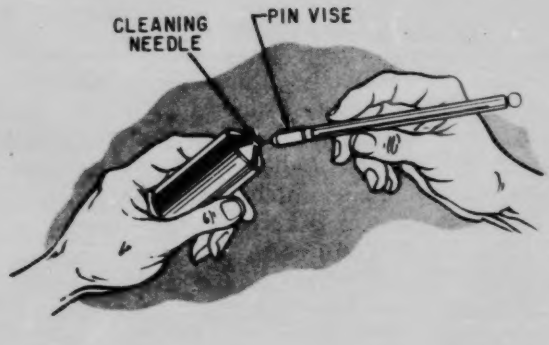


Figure 4-67.—Cleaning injector spray nozzle holes.

pronounced. While the engine with the pump and nozzle fuel system operates at this speed, loosen the fuel line connection at each injection pump one at a time to "cut out" the cylinder. When you find one that makes very little or no difference in the irregular operation of the engine, the injector for that cylinder is probably causing the trouble and needs to be removed and tested. It is seldom that one injector valve alone is responsible for all the trouble. Therefore, you should continue the testing until all injectors have been tested.

CHAPTER 5

COOLING AND LUBRICATING SYSTEMS

All internal combustion engines are equipped with cooling and lubricating systems which work in conjunction with each other to promote efficient engine operation and performance. The cooling and lubricating systems discussed in this chapter, along with their respective components and maintenance requirements, are representative of the types of systems you will be expected to maintain.

Because of the variety of engines used in SEABEE equipment, there are differences in the applications of features of their cooling and lubricating systems. Keep in mind that maintenance procedures and operational characteristics vary from engine to engine; therefore, always refer to the manufacturer's instructions for specific information.

COOLING SYSTEMS

As you have previously learned, the internal-combustion engine produces power by burning fuel within the cylinders, and is therefore sometimes referred to as a "heat engine." However, it was pointed out that only about 25 percent of the heat is converted into useful power for propelling the vehicle or for doing other work. What happens to the remaining 75 percent of the heat? It is largely absorbed by the engine parts or passes out with the exhaust gases. If this heat were not removed quickly, overheating and extensive damage to the engine would result. Valves would burn and warp, lubricating oil would break down, pistons and bearings would overheat and seize, and the engine would soon stop.

The necessity for cooling may be emphasized by considering the total heat developed by an ordinary six-cylinder engine. It is estimated that such an engine operating at ordinary speeds generates sufficient heat to warm a six-room house in freezing weather. Also, peak combustion temperatures in gasoline engines may reach as high as 4500°F, while that of a diesel engine may approach 5000°F. Some of this heat is absorbed by the valves, pistons, cylinder walls, and cylinder head, all of which must be provided with some means of cooling to avoid excessive temperatures. Thus, even though very high temperatures may be reached by the heated gases, the cylinder wall temperatures must not be allowed to rise beyond 400° to 500°F. Temperatures above this result in serious damage, as already indicated. However, for best thermal efficiency, it is desirable to operate the engine at temperatures closely approximating the limits imposed by the lubricating oil properties.

The purpose of the cooling system is to absorb and remove or transfer heat from the engine as well as regulate the operating temperature of the engine for best efficiency. It is estimated that about 25 percent of the heat produced in the combustion chambers by the burning of the fuel is dissipated via the cooling system along with the lubrication and fuel systems. Nearly 50 percent of the heat produced passes out with the exhaust gases. An additional function of the cooling system is that of controlling the temperature in the vehicle passenger compartment to a comfortable range in cold weather, usually through use of hot water heaters.

Air is the only thing which is continually present in large enough quantities to cool the running engine. Vehicles are designed to dissipate the heat from the engine into the air through which they pass. This is accomplished either by direct air cooling or indirectly by liquid cooling. Thus, in the final analysis, the cooling of all automotive engines is actually air cooling, regardless of whether they are classified as air-cooled or liquid-cooled. In this chapter we will be concerned with both types, and the discussion will include a description of the various components of the systems and an explanation of their operation.

AIR-COOLING SYSTEMS

The simplest type of cooling is the air-cooled, or direct, method in which the heat is drawn off by moving air in direct contact with the engine. Several fundamental principles of cooling are embodied in this type of engine cooling. The rate of the cooling is dependent upon the area exposed to the cooling medium, the heat conductivity of the metal used, the volume of the metal or its size in cross section, the amount of air flowing over the heated surfaces, and the difference in temperature between the exposed metal surfaces and the cooling air. Some heat, of course, must be retained for efficient operation. This is done by use of thermostatic controls and mechanical linkage, which open and close shutters to control the volume of cooling air. You will find that air-cooled engines generally operate at a higher temperature than liquid-cooled engines, whose operating temperature is largely limited by the boiling point of the coolant used. Consequently, greater clearances must be provided between the moving parts of air-cooled engines to allow for the increased expansion. Also, lubricating oil of a higher viscosity is generally required.

In air-cooled engines the cylinders are mounted independently to the crankcase so that an adequate volume of air can circulate directly around each cylinder, absorbing heat in passing the cylinders and maintaining cylinder head temperatures within allowable limits for satisfactory operation. In all cases, the cooling action is based on the simple principle that the surrounding air is cooler than the "heat engine." The main components of an air-cooled system are the fan, shround, baffles, and fins. A typical air-cooled engine is shown in figure 5-1.

Fan and Shroud

All stationary air-cooled engines must have fans or blowers of some type to circulate a large volume of cooling air over and around the cylinders. The fan for the air-cooled engine shown in figure 5-1 is built into the flywheel. Notice that the shrouding or cowling, when assembled, will form a compartment around the engine so that the cooling air is properly directed for effective cooling. Air-cooled engines, such as those used on motorcycles and outboard engines, do not require the use of fans or shrouds because their movement through the air results in sufficient airflow over the engine for adequate cooling.

Baffles and Fins

In addition to the fan and shroud, some engines use baffles or deflectors to direct the cooling air from the fan to those parts of the engine not in the direct path of airflow. Baffles are usually made of light metal and are semicircular with one edge in the airsteam, so that the air can be directed to the back of the cylinders. Most air-cooled engines use fins. These are thin, raised projections on the cylinder barrel and head. (See fig. 5-1.) The fins provide more cooling area or surface and aid in directing airflow. Heat resulting from combustion passes by conduction from the cylinder walls and cylinder head to the fins and is carried away by the passing air.

Maintaining the Air-Cooled System

You may feel that because the air-cooling system is so simple it requires no maintenance. Too many mechanics feel this way; many air-cooled engine failures occur as a result. Maintenance of an air-cooling system consists primarily of keeping cooling components clean. Clean components permit rapid transfer of heat

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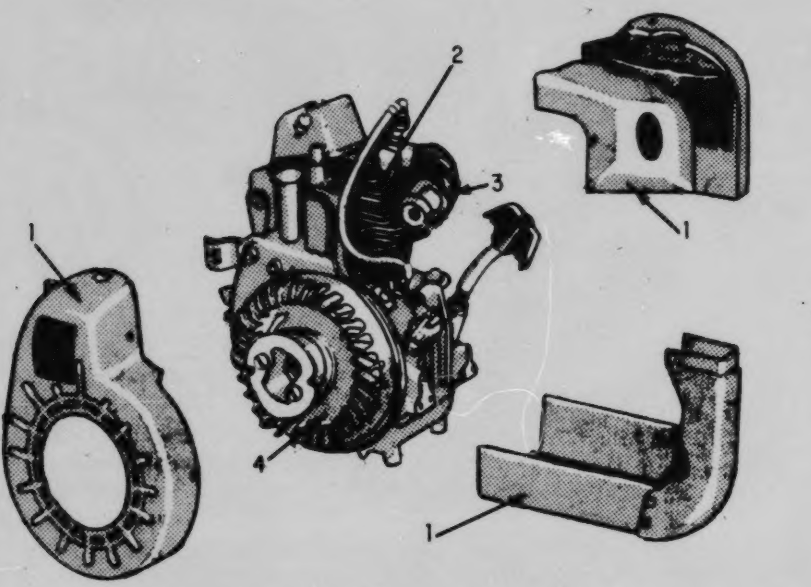


1. Sheet Metal Shrouding
2. Finned Cylinder Head
3. Finned Cylinder Barrel
4. Flywheel Fan

81.518

Figure 5-1.—Air-cooled engine.

and insure that nothing prevents the continuous flow and circulation of air. To accomplish this, keep fans, shrouds, baffles, and fins free of dirt, bugs, grease, and other foreign matter. The engine may look clean from the outside, but what is under the shroud? Accumulation of dirt and debris here can cause real problems.

Keep the area between the engine and shroud clean, too. Paint can cause a problem. Sometimes a mechanic will reduce the efficiency of the cooling system by careless use of paint. The engine may look good but most paints act as an insulator and hold in heat. In addition to keeping the cooling components clean, you should inspect them each time the engine is serviced. Replace or repair any broken or bent parts. Check the fins for cracks or breaks. When cracks extend into the combustion chamber area, the cylinder barrel must be replaced.

Now that we have studied the simplest method of cooling, let's look at a more common, but also more complex, method.

LIQUID-COOLING SYSTEM

Nearly all multicylinder engines used in automotive, construction and materials-handling equipment use a liquid-cooling system. Any liquid used in this type of system is called a COOLANT.

In most liquid-cooled engines, excess heat is removed by the circulation of the coolant through hollow passages surrounding the hottest parts of the engine. Heat first flows into the coolant while the coolant is being pumped through the passages of the cylinder block and up into the cylinder head. The coolant then moves on through similar passages in the head, picks up more heat as it circulates, and finally leaves the engine through an outlet at the top.

After leaving the engine, the coolant passes through an upper hose connection and carries the heat into a radiator. As the coolant flows down through the radiator, the heat is removed by a stream of air forced through the radiator, by the action of a fan only in stationary engines, and by both the fan and forward motion in vehicles.

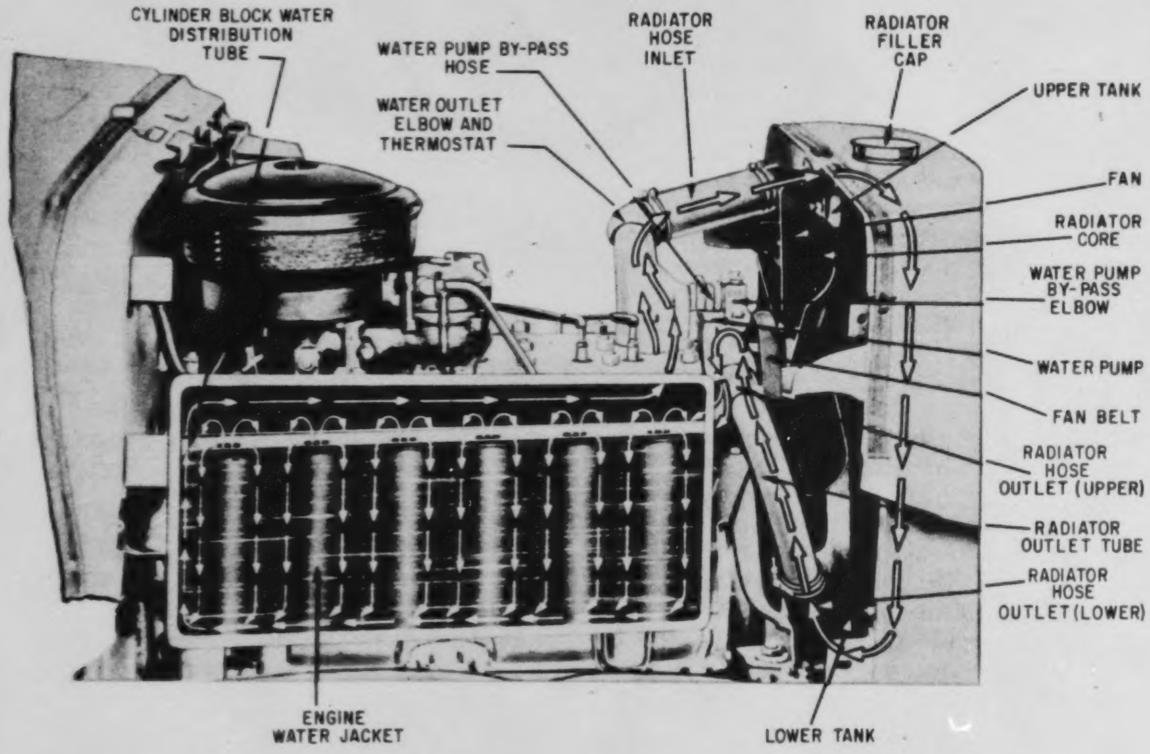
From the bottom of the radiator, the coolant flows through a lower hose connection to the pump where it is again forced into the cylinder block and repeats the cooling cycle, removing more heat from the engine and carrying the heat into the radiator.

The amount of engine heat that must be removed by the cooling system is much greater than is generally realized. To handle this heat load, it may be necessary for the cooling system in some engines to circulate 4000 to 10,000 gallons of coolant per hour. The water passages, the size of the pump and radiator, and other details are so designed as to maintain the working parts of the engine at the most efficient temperature within the limitation imposed by the coolant. Figure 5-2 shows a typical liquid-cooling system and includes most of the components discussed in the following paragraphs.

Radiator

The radiator is probably the key unit in a liquid-cooled system, being a device for holding a considerable volume of coolant in close contact with a large volume of air so that heat may be transferred from the coolant to the air.

The usual radiator assembly consists of a raditor core with a top tank and a bottom tank. The top, or inlet tank, has an outside pipe called the radiator inlet and usually has a coolant baffle inside and above, or at the inlet opening. The radiator filler neck is generally attached to


CYLINDER BLOCK WATER DISTRIBUTION TUBE
WATER PUMP BY-PASS HOSE
WATER OUTLET ELBOW AND THERMOSTAT
RADIATOR HOSE INLET
RADIATOR FILLER CAP
UPPER TANK
FAN
RADIATOR CORE
WATER PUMP BY-PASS ELBOW
WATER PUMP
FAN BELT
RADIATOR HOSE OUTLET (UPPER)
RADIATOR OUTLET TUBE
RADIATOR HOSE OUTLET (LOWER)
ENGINE WATER JACKET
LOWER TANK

81.100

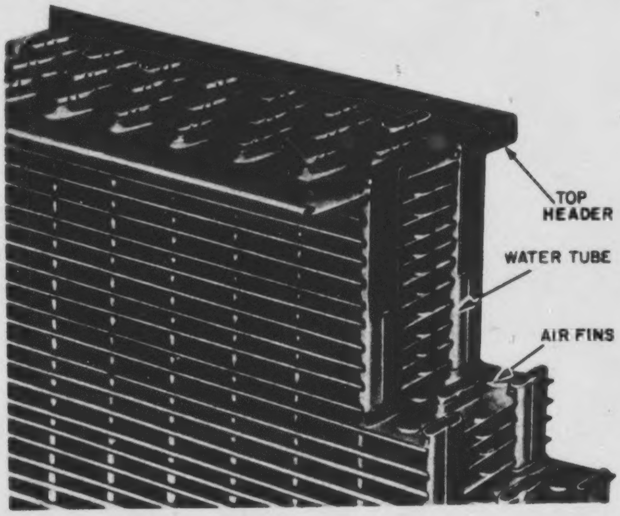
Figure 5-2.—Liquid-cooling system.

the upper part of the top tank and has an outlet to the overflow pipe. The bottom tank also has a pipe which is the radiator outlet. Many radiators for vehicles equipped with automatic transmissions have an inner core located in the bottom tank through which transmission oil is circulated to assist cooling of the transmission.

Practically all cooling systems have tubular radiator cores (fig. 5-3), which consist of a large number of vertical tubes and many horizontal air fins around the tubes. Water passages in the tubes are usually quite narrow, and the tube itself is made of thin metal.

Through the water tubes, the flow of coolant is divided into many small streams which cause a small amount of cooling liquid to be exposed to a comparatively large cooling surface. This results in rapid flow of heat from the coolant to the tubes and air fins. Heat is carried away from the tubes and fins by the movement of the air through the core.

Connections must be provided to carry the water from the engine water jacket to the radiator, and from the radiator back to the engine. Vibration and movement between the radiator and the engine would cause breakage of metal pipe. For this reason, flexible hose is used for radiator connections. Sometimes, pieces of pipe are placed in sections of long hoses. This reduces the dangers of hose collapse and makes a stronger connection.



81.102
Figure 5-3.—Tubular radiator core construction.

Radiator Pressure Cap

The raidator pressure cap (fig. 5-4) is used on nearly all modern engines. The pressure cap closes off the overflow pipe and prevents loss of coolant during normal operation. It also allows a certain amount of pressure to develop within the cooling system. The pressure raises the boiling point of the coolant approximately 3° for each pound and permits the engine to operate at higher temperatures without loss of coolant from boiling.

The pressure cap contains two spring-loaded valves. The larger valve is called the pressure valve and the smaller one is called the vacuum valve. A shoulder in the radiator filler neck provides a seat for the bottom of the cap assembly and a gasket on this seat prevents leakage between the cap and the filler neck.

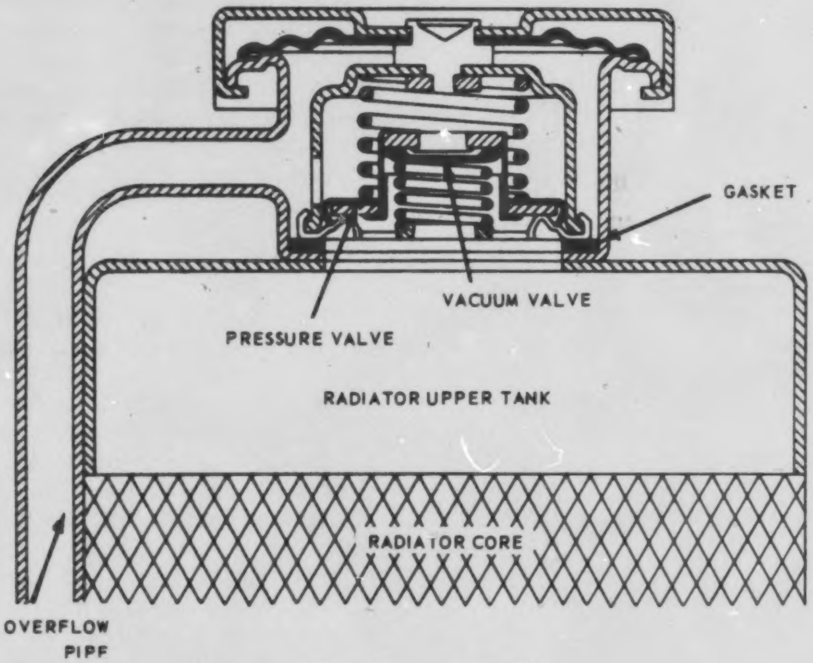
The pressure valve acts as a safety valve to relieve extra pressure within the system. The cooling system may be designed to operate at various pressures; 4 to 17 psi, depending on the manufacturer's specifications. The pressure valve in the cap is preset by the manufacturer. When replacing a pressure cap, make sure you use a cap with the proper pressure setting which is usually marked on the top surface of the cap.

The vacuum valve opens only when the pressure within the cooling system drops below the outside air pressure as the engine cools down. This automatic action of the vacuum valve prevents collapse of hose and the radiator.

CAUTION: ALWAYS REMOVE THE RADIATOR CAP SLOWLY AND CAREFULLY. Removing the cap from a hot, pressurized radiator can cause serious burns from escaping steam and coolant.

Water Pump

The water pump is the heart of the cooling system. Most engines use a centrifugal water pump, like the one shown in figure 5-5, which



81.103

Figure 5-4.—Radiator pressure cap.

provides a large volume capacity and is nonpositive in displacement. This type pump has an impeller with blades which force the coolant outward as the impeller rotates. The shaft on which the impeller is mounted is usually driven by a fan belt and revolves in a bushing or in ball bearings inside the housing, as shown in the illustration. Also shown in the illustration is the nonadjustable seal assembly, which prevents leakage around the externally driven water pump shaft. For different cooling systems, pumps vary considerably in construction of seals, bearings, mounting, and drive.

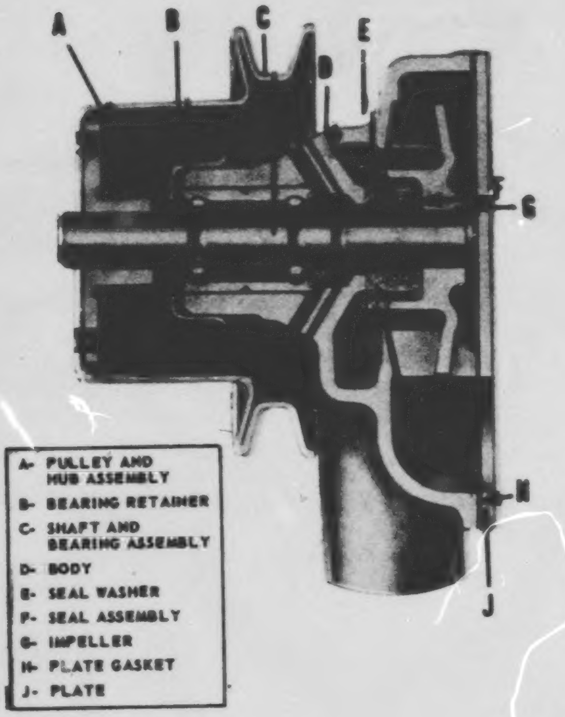
Fan and Shroud

The engine fan is usually mounted on the end of the water pump shaft and is driven by the same belt that drives the pump. The fan pulls a large volume of air through the radiator core which cools the hot water circulating through the radiator. Besides removing heat from the water in the radiator, the flow of air created by the fan causes some direct cooling of the engine itself. Some engines are equipped with a shroud that improves fan efficiency by assuring that all the air handled by the fan passes through the radiator.

Fan blades are spaced at intervals around the fan hub to aid in controlling vibration and noise. They are often curled at the tip to increase their ability to move air. Except for differences in location around the hub, most blades have the same pitch and angularity.

Bent fan blades are very common and result in noise, vibration, and excess wear on the water pump shaft. You should make it a practice to visually inspect the fan blades, pulleys, pumpshaft end play, and drive belts at every preventive maintenance inspection.

At 300 rpm an 18-inch fan will consume over 2 hp. This power drain increases rapidly with an increase in engine speed. Since the fan is



81.101

Figure 5-5.—Water pump.

required primarily at low engine speeds, couplings have been devised which disconnect the fan above certain speeds.

The FAN DRIVE CLUTCH is a fluid coupling which contains silicone oil. Fan speed is controlled by the torque-carrying capacity of the oil. The more silicone oil in the coupling, the greater the fan speed; the less silicone oil, the slower the fan speed.

Two types of fan drive clutch controls are in use today. One type uses a BIMETALLIC STRIP and control piston in the front of the fluid coupling. The bimetallic strip bows outward with an increase in surrounding temperatures and allows the piston to move outward. The piston opens a valve which regulates the flow of silicone oil into the coupling from a reserve chamber. When the valve is closed the oil is returned to the reserve chamber through a bleed hole.

The BIMETALLIC SPRING type fan drive clutch uses a spring connected to an opening plate. This produces an action much the same as the bimetallic strip type of control. Both types of controls cause the fan speed to increase with a rise in temperature and to decrease as the temperature goes down.

Water Jacket

The water passages in the cylinder block and cylinder head form the engine water jacket. (See fig. 5-2.) In the cylinder block, the water jacket completely surrounds all cylinders along their full length. Within the jacket, narrow passages are provided between the cylinders for coolant circulation around them. In addition, water passages are provided around the valve seats and other hot parts of the cylinder block. In the cylinder head, the water jacket covers the combustion chambers at the top of the cylinders and contains passages around the valve seats when the valves are located in the head.

The passages of the water jacket are designed to control circulation of coolant and provide proper cooling throughout the engine. The pump forces coolant directly from the lower radiator tank connection into the forward portion of the cylinder block. This type of circulation would, obviously, cool number one cylinder first, causing the rear cylinders to accept coolant progressively heated by the cylinders ahead. To prevent this condition, the L-head block in figure 5-2 is equipped with a water distribution tube that extends from front to rear of the block, having holes adjacent to (and directed at) the hottest parts of each cylinder. I-head engines are equipped with ferrule type water directors which direct a jet of water toward the exhaust valve seats.

Thermostats

Automatic control of the engine's temperature is necessary for efficient engine performance and economical operation. If the engine is allowed to operate at a low temperature, sludge buildup and excessive fuel consumption will occur. On the other hand, overheating the engine or operating it above normal temperature will result in burnt valves and faulty lubrication. The latter usually causes early engine failure.

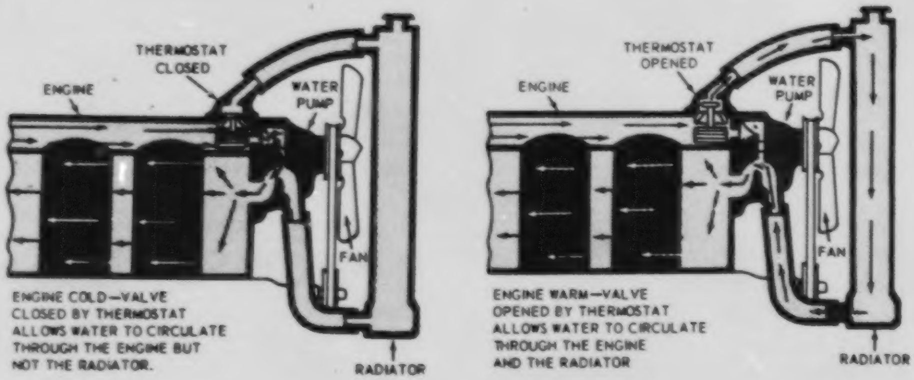
Since all engine parts are in a contracted state when cold, the engine temperature should be brought to normal as quickly as possible. The water pump starts coolant circulating the moment the engine is started, which is undesirable for cold weather operation. To restrict coolant circulation, a thermostatically controlled valve, or thermostat, is installed in the cylinder head water outlet. This valve allows coolant to circulate freely only within the block until the desired temperature is reached. This shortens the warmup period. A bypass is used to direct the water from the block back to the pump when the passage to the radiator is blocked by the closed thermostat (fig. 5-6).

Thermostats are manufactured in several designs, the most common being the bellows and the pellet. The BELLOWS thermostat (fig. 5-7) consists of a round bellows which contains a small amount of a highly volatile liquid (such as ether). The liquid creates a pressure when heated. This pressure opens the valve as the engine warms up and allows the coolant to circulate. Should the bellows become punctured or ruptured, the thermostat will remain in the open position.

The PELLET thermostat (fig. 5-8) uses the piston and spring pressure principle. A small mass of powderlike crystals is enclosed within a small sealed receptacle (pellet) from which a small piston rod extends to the valve. The crystals, being of high expansion valve, expand under heat and push the piston sufficiently to overcome spring tension. This opens the valve. Spring tension closes the thermostat when the crystals contract. Operative failure of this kind of thermostat is caused by impregnation of the pellet with coolant, causing it to remain in open position.

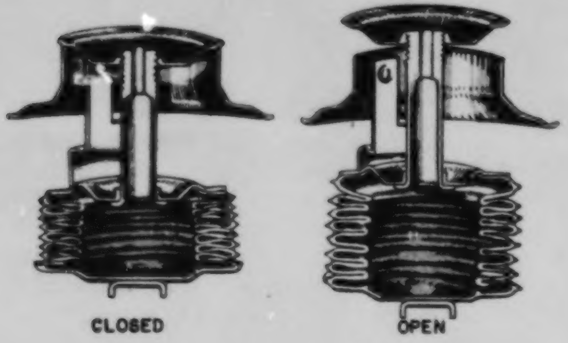
Although a thermostat is designed to open at a specific temperature, most thermostats vary a few degrees in the temperature at which they begin to open. In addition, they may require a temperature from 20° to 25° higher before they are fully open. For instance, a thermostat designed to open at 150°F might begin to open at any temperature between 146° and 154°F. This same thermostat should be fully open at 170° to 175°F.

Some stationary engines and large trucks are equipped with shutters which supplement the action of the thermostat in providing a faster warmup and in maintaining proper operating temperatures. When the engine coolant is below a predetermined temperature (185° to 195°F), the shutters, located in front of the radiator,

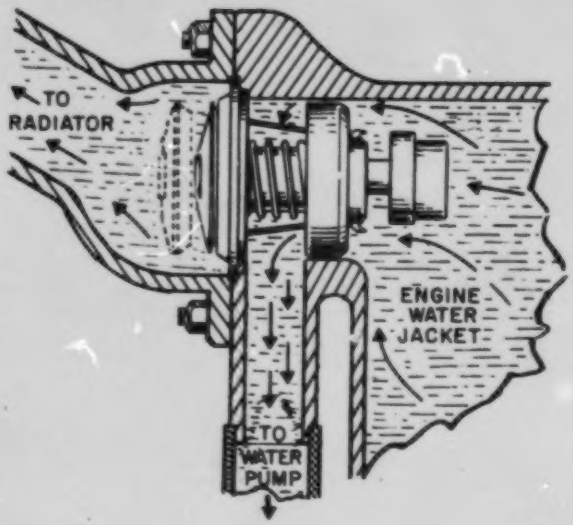

ENGINE
THERMOSTAT CLOSED
WATER PUMP
FAN
RADIATOR
ENGINE COLD—VALVE CLOSED BY THERMOSTAT ALLOWS WATER TO CIRCULATE THROUGH THE ENGINE BUT NOT THE RADIATOR.
ENGINE
THERMOSTAT OPENED
WATER PUMP
FAN
RADIATOR
ENGINE WARM—VALVE OPENED BY THERMOSTAT ALLOWS WATER TO CIRCULATE THROUGH THE ENGINE AND THE RADIATOR

81.105

Figure 5-6.—A thermostat in operation.



81.519
Figure 5-7.—Bellows thermostat.



81.520
Figure 5-8.—Pellet thermostat.

remain closed and restrict the flow of air through the radiator. Then as the coolant reaches proper temperature, the shutters start to open. Two methods are used to control the shutter opening. Stationary engines use a SHUTTERSTAT (long thermostatic valve) connected to the engine cooling system with hoses or pipes that allow the engines coolant to circulate through the valve. The temperature of the coolant, when it reaches the predetermined temperature, causes the valve to expand, extending a rod which through linkage, forces the shutters open. Trucks, when equipped with an airbrake system, use a smaller thermostatic valve that actuates an air valve. This air valve allows air pressure from the air tank to enter the air cylinder attached to the shutter operating linkage thus forcing the shutters open.

Should the shutterstat fail during operation, it will remain open the same as all thermostats used on Navy owned equipment. Lubrication to the linkage, and replacement of the valve should failure occur, are normally the only maintenance needed.

Overflow Tank

An overflow, sometimes referred to as a surge tank or expansion tank, serves as a receptacle for coolant forced out of the radiator overflow pipe and provides for its return to the system. As the engine cools, the balancing of pressures causes the coolant to syphon back into the radiator. This requires a plain cap on the radiator and a pressure cap on the overflow tank.

Cooling systems using an overflow tank are known as closed cooling systems. Coolant is usually added to this system through the overflow tank which is marked for proper coolant level. NEVER remove the plain cap located on the radiator unless you are positive the system is cold. If there is any pressure in the radiator, it will spray you with hot steam and coolant. Use extreme caution whenever you work around a closed cooling system.

Temperature Gage

The engine temperature gage is made up of two principal parts: the gage unit mounted on the instrument panel, and the engine thermal unit. When operated on the principle of the Bourdon tube, the temperature gage is acutuated by pressure from a bulb, which is screwed into the water jacket of the engine. The heat of the water vaporizes the liquid in the bulb, and the vapors flow through a capillary, which is a very small tube connecting the bulb to the gage. The greater the heat, the more vapor given off, the greater the pressure, and the higher the temperature indicated on the gage.

When installing the temperature gage or repairing other parts of the engine, be careful not to kink the tube connecting the gage and sending unit. Although it looks like an ordinary wire, this tube contains the fluid which operates the gage unit on the instrument panel. A damaged temperature gage must be replaced as a whole unit and cannot be repaired in the shop.

Some vehicles are equipped with an electric temperature gage. The higher temperature, the greater the current passing through the coils to the indicating unit, which in turn moves the needle to register the engine temperature.

Coolants and Antifreeze

Since water is easily obtained, cheap, and has the ability to transfer heat readily, it has served as a basic coolant for many years. Some properties of water, such as its boiling point, freezing point, and natural corrosive action on metals, limit its usefulness as a coolant. To counteract this, an antifreeze is used. The most commonly used type of antifreeze is ethylene glycol. It is chemically compounded of a mixture of ethylene and glycerine derivatives and is manufactured under many trade names. Maximum freezing protection is achieved by mixing 60% ethylene glycol with 40% water. This will protect the cooling system to about -62°F. Ethylene glycol has a very high boiling point, does not evaporate easily, is noncorrosive and practically nonflammable.

SERVICING THE LIQUID-COOLING SYSTEM

Because the effects or damages that result from an improperly serviced cooling system usually occur gradually, this system tends to be neglected. However, the requirements of modern liquid-cooled engines and the severe conditions under which they often operate make it necessary that the cooling system be maintained at maximum efficiency. This is particularly true in the case of V-8 engines, especially the larger ones, because of the increase in the heat generated and the slight margin of safety provided by the design of the cooling system. In fact, only a slight loss in circulation or cooling efficiency can be critical, especially when the vehicle is loaded with power equipment, which places an additional load on the engine at idle or in slow traffic on hot days. In view of this, it is essential that proper inspection and servicing be accomplished to keep the cooling system in good condition. In this portion of our study, you will be introduced to several service operations pertaining to the system, including cleaning and flushing, rust prevention, use of antifreeze, and cooling system testing.

Cleaning and Flushing

Accumulations of rust and scale in the cooling system eventually restrict the circulation of coolant, and the engine is likely to overheat. A good cleaning compound can be used to overcome this condition. In using the compound, you must be careful to follow the manufacturer's instructions. Following this, the system should be neutralized, since cleaners contain strong acids which, if not completely removed, attack parts of the cooling system.

CAUTION: Avoid spilling any cleaning compound on the skin, clothing, or vehicle paint.

Some manufacturers recommend reverse-flushing; i.e., forcing water and air through the system in the direction opposite to normal circulation. This tends to loosen the scale and flush it–along with any sediment–out of the system.

Some CM shops are equipped with reverse-flushing equipment. It usually consists of a flushing gun device similar to that shown in

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figure 5-9. In the figure, a gun is being used on the radiator which has been filled with water and the cap installed. Notice that the lower radiator hose has been disconnected from the water pump and that the gun is used to force water and air through this hose and into the radiator. The air pressure is applied intermittently to loosen scale and sediment better. Excessive air pressure should be avoided to prevent damage to the radiator. Starting and stopping the waterflow produces a fluctuation of pressure and tends to loosen all foreign matter clinging to the water passages in the radiator core. As shown in the figure, the upper hose has been disconnected from the engine so that the water can be directed to the ground or floor drains.

Reverse-flushing equipment can also be used, as shown in figure 5-10, to reverse-flush the engine block and head. First, remove the thermostat and disconnect the upper radiator hose between the water outlet and the radiator. Then disconnect the lower radiator hose at the water pump and insert the flushing equipment in the upper radiator hose. Reverse-flush the system by sending water and air through the water jackets and coolant passages. Following flushing, the thermostat and hoses can be replaced and the system refilled. Where reverse-flushing equipment is unavailable, you can still reverse-flush the system with an ordinary garden hose. This is often effective following the use of a cleaner and neutralizer.

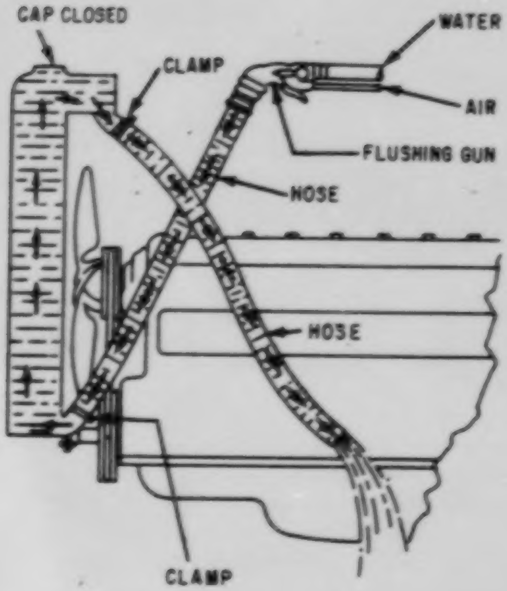

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Figure 5-9.—Reverse flushing of radiator.

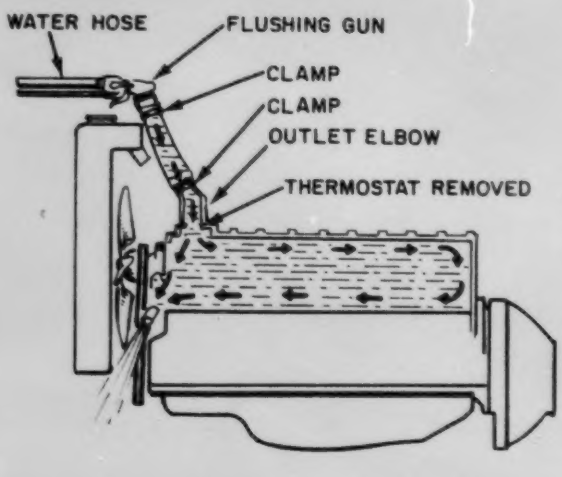

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Figure 5-10.—Reverse flushing of water jackets.

Preventing Rust

Rust is the result of iron and oxygen present in the system and it can only be controlled by manintaining full-strength corrosion protection at all times. An indication of the presence of rust, scale, or grease can be obtained by running your finger around the inside of the filler neck of the radiator. The grease and rust deposits collected on your finger will show if this servicing is required.

The use of inhibitors or rust preventives reduces the corrosion of metals and prevents the formation of scale. Inhibitors are not cleaners and do not remove rust or scale already formed. Treating the cooling system with an inhibitor consists of adding it to the coolant. The inhibitor should be renewed periodically, especially if the system has been recently cleaned or flushed. Permanent type antifreeze contains an inhibitor so that during cold weather a separate inhibitor need not be used. Inhibitor in the required amount should always be used in the cooling system after antifreeze has been drained. The required amount of inhibitor is indicated on the container and depends on the cooling system capacity.

Using Antifreeze

Permanent antifreeze of the ethylene glycol type is used to protect the cooling system during cold weather. Before installing antifreeze in the system, you should check for leaks and, if necessary, clean and flush the cooling system. Also, you should check the thermostat, pressure cap, and all hoses. If the system has a radiator overflow tank, you should rinse it by filling with water and then completely draining.

After filling the system to about one-third capacity with water, you are ready to add the antifreeze. But just how much antifreeze should you use? This will depend on the capacity of the cooling system and the lowest expected temperature. The system should be protected to at least 10° below the lowest expected temperature. Table 5-1 indicates the number of pints of permanent antifreeze needed per gallon of cooling system capacity to afford protection to the various temperatures listed. Thus, if your cooling system (with heater) had a capacity of 22 quarts (5 1/2 gallons), you would need to use approximately 18 pints (2 1/4 gallons) of antifreeze to afford adequate protection to -10°F or 19 1/4 pints (slightly over 2 3/8 gallons) to protect to -20°F. In this connection, you should note that the maximum protection available is obtained by using about 4 3/4 pints of ethylene glycol for each gallon of the cooling system capacity. This means that the solution would then contain about 60 percent ethylene glycol by volume to protect to -60°F. When you attempt to use a greater proportion of antifreeze than this, little—if any—advantage results. The reason is that a straight ethylene glycol (100 percent) affords less protection than one containing 60 percent ethylene glycol and 40 percent water. In other words, up to a point the water acts as an "antifreeze" for the ethylene glycol.

Table 5-1.—Permanent Antifreeze Needed Per Gallon of Cooling System Capacity.

Protection to:	Pints
+10°F	2
0°F	2 3/4
-10°F	3 1/4
-20°F	3 1/2
-30°F	4
-40°F	4 1/4
-50°F	4 1/2
-60°F	4 3/4

After adding the required amount of antifreeze, you should fill the system with clean water, leaving room for the expansion, and operate the engine to mix the solution. Then add water, if necessary, to bring the coolant level to that prescribed for the vehicle. You should then stop the engine and check the solution with an antifreeze hydrometer—to be discussed later—in order to make sure the system is protected to the desired temperature.

Most modern high compression engines, especially those equipped with air-conditioning, require the use of antifreeze year round for efficient cooling system and engine performance.

Cooling System Testing

It is often necessary to check the cooling system for leaks that are hard to find. Leaks in the cooling system should not be permitted to continue, since boiling and overheating will tend to occur, resulting in breaking down the oil film and possibly damaging the engine. Air will be drawn into the system if leaks are present between the radiator and water pump, causing foaming and loss of coolant as well as accelerating rusting and corrosion. To check for such leaks, connect a hose to the overflow pipe and place the other end of the hose in a pail of water. If the system is full and the warmed-up engine is running, any air drawn into the system will be indicated by bubbling in the pail of water. Air leaks are usually corrected by tightening the hose clamps of the hose connecting the radiator to the water pump or replacing the hose if necessary. The trouble also may be caused by a leaking water pump or exhaust gas leakage.

Exhaust gas leaking into the cooling system, usually as a result of a leaking cylinder head gasket, will result in damage to the system due to the action of acids formed in the system. To check for exhaust gas leakage, remove the fan belt, upper radiator hose, and thermostat. Then drain out some coolant until its level is just above the top of the cylinder head. Then if the engine is accelerated quickly several times, exhaust gas leakage will generally reveal itself by bubbling at the thermostat outlet or by a rise in coolant level beyond that caused by normal coolant expansion.

A radiator pressure tester can also be used to check for leaks. The device is installed on the radiator filler neck in place of the pressure cap. Then air pressure is applied and the gage observed for a pressure drop which would indicate a leak. Pressure should not exceed that recommended by the manufacturer. On a system with a 14-pound pressure cap, for example, do not apply more than 15 psi. If the leak cannot be located externally, inspect the engine oil to determine whether coolant is leaking into the crankcase due to a cracked cylinder block or leaking head gasket.

To check for compression or combustion leakage, run the engine until it reaches normal operating temperature. Then pressurize the system with the engine running. Fluctuating pressure as the engine is accelerated indicates a combustion leak. In the case of a V-8 engine, you can determine which bank is at fault by disconnecting the spark plug leads from one bank and running the engine on the other. The combustion leak is in the bank furnishing the power when the pressure fluctuates. To determine which cylinder is leaking, disconnect the spark plug wires one at a time and observe the tester dial. When the plug wire is removed from the leaking cylinder, the indicator will stop fluctuating. If more than one cylinder leaks, removing the plug lead from an offending cylinder will cause the fluctuation to become less frequent. If tightening the cylinder head to specifications does not stop the leak, replace the head gasket and recheck for leakage.

The radiator pressure tester can also be used to test the radiator pressure cap by using an adapter provided for this purpose. The adapter is screwed onto the lower end of the tester, and the pressure cap is installed on the other end of the adapter. The cap rubber gasket should be wet to insure an airtight seal. Then by applying air pressure as specified for the particular cap, you can determine if it is capable of retaining the pressure as it should.

Another tester used with cooling systems is the ANTIFREEZE HYDROMETER which is used to determine if adequate protection against freezing is afforded by the antifreeze solution in use. This hydrometer shows the specific gravity of the solution, thus giving you an indication of what percentage of the solution is water and what percentage is ethylene glycol. Then by referring to a chart, which corrects for the coolant temperature, you can determine if additional compound should be added to the system. The accuracy of the tester can be checked by taking a test reading of a mixture containing one part anitfreeze compound and two parts water, which should test to 0°F. The tester manufacturer's instructions should be followed for proper use and care of the hydrometer. Accurate readings are not possible if the float and the inside of the glass barrel are dirty.

Before reading the tester, you should fill and empty the hydrometer barrel several times in order to equalize the temperature of all parts. First read the first number or letter on the float above the surface of the liquid and then note the solution temperature from the first division or number above the top of the indicating column of the thermometer. These two readings should be made at the same time and as soon as possible after drawing the solution into the hydrometer. The freezing protection of the solution is determined from float and thermometer readings by referring them to the chart on the hydrometer. Tests will be inaccurate if made immediately after adding water or antifreeze. Most antifreeze hydrometers give best reading accuracy at solution temperatures around 110°F. Even with hydrometers designed to read at solution temperatures below 0°F, tests should always be made with the temperature of coolant above 60°F, if possible, because the solution is more viscous when cold. This condition prevents the float from finding its true level quickly and may result in a false float reading.

REPAIRING COOLING SYSTEM COMPONENTS

The individual components of the cooling system which require servicing and repair include the water jacket in the cylinder block and head, radiator, hoses, water pump, fan and fan belt, and thermostat. Repair of these components will be discussed separately.

Water Jacket

Some maintenance aspects in connection with the water jacket have already been discussed, including cleaning and preventing rust and corrosion. But where water jackets are badly clogged and do not respond to regular or reverse-flushing, some of the core hole plugs can be removed from the cylinder block and head. With a suitable length of small copper tubing attached to the flushing gun nozzle, the water jacket can be flushed through the openings. New plugs should then be installed. Any plugs which show signs of leaking or rusting must be replaced. All drain plugs should be kept free of rust and scale. Gaskets must be in good condition to prevent both internal and external leaks. If there are external leaks around gaskets, there may also be internal leaks into the engine. Proper tightening of the head bolts or capscrews with a torque wrench is essential for preventing leaks around the head gasket. It this fails to correct the difficulty, the gasket must be replaced.

Radiator

The radiator should be checked for leaks, particularly where the tanks are soldered to the core, since vibration and pulsation from pressure can cause fatigue of soldered joints or seams. Neglect of small leaks may result in complete radiator failure, excessive leakage, rust clogging, and overheating difficulties. Thus, it is extremely important to keep the radiator mounting properly adjusted and tight at all times and to detect and correct even the smallest leaks. A leak usually reveals its presence by scale marks or watermarks below the leak on the outside of the core. Contrary to popular conceptions, permanent antifreeze does not leak through spaces where water won't pass. What actually occurs is that the antifreeze leak is more noticeable, since it does not evaporate as quickly as water. Often, small leaks can be effectively mended by using one of several commercially available radiator sealers (powders or liquid-solder compounds) which harden upon contact with the air, thus sealing off any small openings. Leaks can also be repaired by ordinary soldering. When large leaks or considerable damage is present, removal of the radiator for extensive repair or replacement is usually required.

Bent fins should be straightened and the radiator core checked for any obstructions tending to restrict the airflow. Radiator air passages can be cleaned by blowing them out with an airhose in the direction opposite to the ordinary flow of air. Water can also be used to soften obstructions before applying the airblast. In any event, the cleaning gets rid of dirt, bugs, leaves, straw, and other debris which otherwise would clog the radiator and reduce its cooling efficiency. Sometimes screens are used in front of radiator cores to prevent this type of clogging.

The radiator can be checked for internal clogging by removing the hose connections and draining the radiator. Then introduce a stream of water into the top from a garden hose and observe the flow coming out at the bottom. If the flow is sluggish, the radiator is partially clogged. Another way to check for this condition is to feel the radiator with your hand after the engine has been operated for some time. The radiator should be warm at the bottom and hot at the top, with the temperature increasing uniformly from bottom to top. Any clogged sections will feel cool.

CAUTION: Be sure the engine is not running when making this test to avoid injury from the fan.

Where use of cleaning compounds and reverse-flushing fails to relieve a clogged core, the radiator must be removed for mechanical cleaning. This requires the removal of upper and lower tanks and rodding out the accumulated rust and scale from the water passages of the core.

The radiator pressure cap should also be checked for condition and proper operation. If it is dirty, the cap can be cleaned with soap and water and then rinsed. The seating surfaces of the vacuum and pressure valves should be smooth and undamaged. The valves should operate freely when pressed against their spring pressures and should seal properly when closed. By using the pressure tester, you can quickly check the cap for proper operation.

Hoses

All hoses and tubing should be checked frequently for leakage and general condition. The leakage may often be corrected by tightening or replacing the hose clamps. Deteriorated hoses should be replaced to preclude future troubles. For example, hoses sometimes rot on the inside, allowing tiny fragments to flow through the system and become lodged in the radiator, tending to clog it and cause overheating. Any restriction in the radiator slows circulation so that the suction of the water pump creates a low-pressure pocket, tending to permit the water to convert immediately to steam and perhaps cause the engine coolant to boil over. Therefore, all old, cracked, or spongy hose should be replaced as soon as the condition is discovered. The lower radiator hose is a particular suspect because it is on the vacuum side of the pump. When this hose becomes soft with age, it tends to collapse, with the result just described. You can check such hoses as well as others by squeezing them; if they are "mushy" they should be replaced. However, where spiral spring stiffeners are used to control the tendency to collapse, such a test will not work and the hose will need to be removed for inspection.

Water Pump

Normally, the water pump requires little in the way of maintenance in day-to-day operation. Nearly all water pumps use sealed bearings, so that even lubrication service has been eliminated. However, where provided, the air vent at the top of the housing and the drain hole at the bottom should be checked to make sure they are not plugged with grease or dirt. Pumping failures are most often caused by a broken or loose drive belt, requiring that the belt be replaced or adjusted. Leaks, which are also quite common, may sometimes be corrected by replacing the pump gasket. However, after long service, the pump may develop a leak around the shaft or become noisy due to worn bearings or other defects. It will then require replacement or rebuilding. Pumping capacity can be reduced as a result of edge wear of impeller blades and wear of the pump housing caused by abrasive action of sand or rust in the system. Sometimes a pump may cease to circulate coolant because of eroded impellers or vanes or a buildup of rust or mineral deposits on the impellers or vanes. The pump operation can be checked with the engine running by squeezing the upper radiator hose to ascertain the presence of a pressure surge.

Whether a defective pump is replaced or rebuilt depends on parts supply and cost. Repair kits are sometimes available for rebuilding water pumps. In most cases, however, it is more economical simply to replace the pump. In fact, there are some pumps for which repair kits are not made. In any event, the removal and installation procedures, as well as the rebuilding procedure (if applicable), will vary on different pumps. Therefore, the applicable shop manual must be consulted for the step-by-step procedures and any specifications, clearances, tolerances, and so on, pertinent to the job.

When you replace a pump, install a new gasket. Make sure the mating surfaces are clean and smooth. The application of sealer to both sides of the gasket is often recommended. Then after refilling the system, the pump should be checked for leaks, noise, and proper operation.

Fan and Belt

A bent or distorted fan or one with a loose blade should be replaced. Where the fan is merely loose on its mounting, tightening is in order. Loose fan belts can be adjusted for proper tension, usually by shifting the generator on its mounting. A common method for measuring belt tension is to press down on the belt at a point midway between the generator and fan pulley; then measure the amount of deflection. The amount of deflection will vary and should be set to the manufacturer's specification. The amount of deflection will depend on whether the belt is new or used and the distance between the pulleys.

A belt adjustment that is just tight enough to prevent slipping may be considered correct. A belt that is too tight can cause the generator or alternator bearing to wear rapidly. A belt that is too loose may squeak when the engine is accelerating. When a belt is misalined, a squeak may occur at idle speed. Correction can be made by using spacers on the accessories or by filing brackets. However, if the squeak is caused by a nonuniform groove or eccentric pulley, the pulley should be replaced.

Replacement of a defective belt is usually made by loosening the generator mounting bolts and the generator adjusting arm and moving the generator closer to the engine. The belt can then be removed over the fan and a new one installed and adjusted.

Thermostat

There are no repairs or adjustments to be made on the ordinary thermostat. The unit must be replaced if it fails to operate properly. The temperature at which the thermostat opens is very important and should be tested whenever the cooling system operating temperature indicates the need. To remove the thermostat, drain the coolant until its level is below the thermostat, remove the hose connecting the thermostat outlet to the radiator if necessary, and remove the outlet retaining capscrews. The thermostat can then be removed and checked for condition and operation. If it is excessively rusted or bent, or if the valve is not tightly closed, the thermostat must be discarded.

If the thermostat appears to be in good condition, its operation can be tested as shown in figure 5-11. The thermostat is suspended in a container of water together with a high-temperature thermometer. Then by heating the container on a stove or hotplate, the temperature at which the thermostat begins to

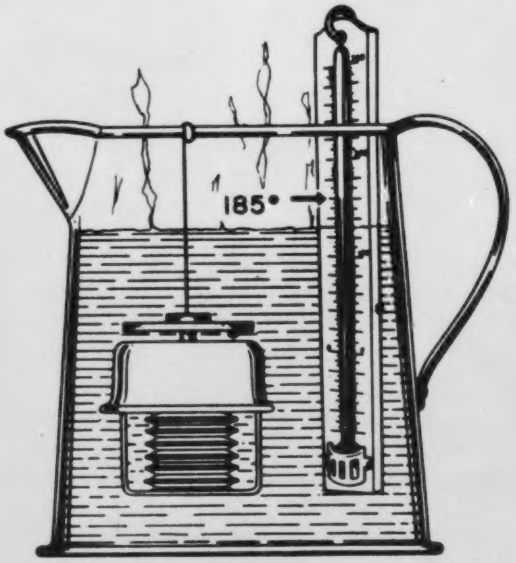

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Figure 5-11.—Testing a thermostat.

open, as well as the full-open temperature, can be determined. If the thermostat fails to respond at specified temperatures, it should be discarded. Specifications vary on different vehicles, but on one popular make, the opening temperature is 180° to 185°F, and the full-open temperature is 200° to 202°F. If the tests are satisfactory, the thermostat can be reinstalled. A new gasket–or gaskets in the case of some V-8 engines–should be used and the capscrews tightened to the specified torque. Then the cooling system can be filled and the engine operated to check for leaks as well as proper thermostat action.

You should now have a good understanding of the service and repair requirements that pertain to cooling systems in general. However, it is good to remember that specific procedures or those peculiar to the system on a particular vehicle will require reference to the applicable manufacturer's or other technical publication.

ENGINE LUBRICATION SYSTEMS

Nearly all internal combustion engines are equipped with an internal lubrication system. Without lubrication, an engine would quickly overheat, and its working parts would seize or stick because of excessive friction. All the moving parts must be adequately lubricated to assure minimum wear and long engine life. With this in mind, we will explain the purposes of lubrication, the function of the different components found in lubrication systems, the different types of systems in use today, and the maintenance requirements of representative systems.

PURPOSES OF LUBRICATION

The primary function of engine lubrication is to reduce friction between moving parts. Lubrication supplies a thin film of oil which prevents metal-to-metal contact, thus greatly reducing friction. The crankshaft, connecting rods, bearings, pistons, piston rings, valve stems, valve tappets, gears, drives, couplings, and bearings are the main parts which must be lubricated to guard against friction.

Helping to cool the engine is another function of the lubrication system. The oil goes through some very hot regions in the engine, and heat is absorbed by the oil, thus raising the oil temperature. The heat so absorbed is carried back to the oil pan, from which it is dissipated into the surrounding air.

Other purposes of lubricating oil are: absorbing shocks between bearings and other engine parts; forming a seal between piston rings and cylinder wall; and helping to clean the engine parts.

As a shock-absorbing agent, oil around the piston bearings and journals acts as a cushion against the jars they receive from the hammerlike blows of the thrusts of the piston. A load of as much as one and a quarter tons is suddenly thrown upon the top of the piston when combustion takes place. This sudden thrust on the piston is carried through the piston pin and connecting rod bearings. Oil helps quiet the piston movement and reduces the wear of its parts.

Piston rings must form a gastight seal with the cylinder walls. The lubricating oil delivered to the cylinder walls helps in this respect. The oil film also provides lubrication of the rings so that they can move easily in the piston ring grooves and on the cylinder walls.

As oil circulates through the engine, it tends to wash off and carry dirt, particles of carbon, and other foreign matter into the crankcase, where the larger particles drop to the bottom of the pan. The oil filter removes many of the smaller particles.

LUBRICATION SYSTEM COMPONENTS

All modern engines are lubricated under pressure. The oil supply is carried in the oil pan attached to the underside of the crankcase, from which it is drawn up and forced through a network of tubes, pipes, and drilled passages by the oil pump. The other main components of the system include the oil pressure gage, oil strainer, oil filter, oil level gage, and oil temperature regulator (oil cooler).

Oil Pump

The oil pump is the heart of the engine lubricating system. Depending on the type of engine, the pump will be mounted either inside or outside the crankcase. The two common types of oil pumps generally used in automotive engines are the gear and the rotary.

The GEAR pump (fig. 5-12) consists of two pump gears mounted within a close fitting housing. One of these two pump gears is driven by the pump's drive shaft which in turn actuates the other gear mounted on a stub shaft. The two gears are in mesh and rotate in opposite directions. Oil is picked up in the spaces between the gear teeth and the housing. This oil is then carried around to the pump outlet where it is discharged. Pressure is developed because of restrictions in the system caused by closely mated parts in the engine and pump. The gear pump may be driven directly from the camshaft or indirectly by the distributor.

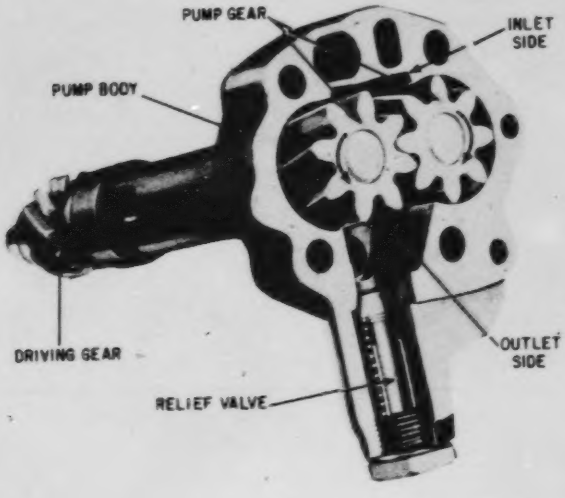

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Figure 5-12.—Gear oil pump.

The ROTARY pump (fig. 5-13) has an inner rotor with lobes that match similar shaped depressions in the outer rotor. The inner rotor is offcenter from the outer rotor. As the inner rotor turns, it turns the outer rotor with it. As the two rotors turn, the openings between them are filled with oil. This oil is forced out from between the rotors as the inner rotor lobes enter the opening in the outer rotor. As you can see in figure 5-13 the inner rotor lobes have very little clearance as they approach the discharge. This allows the oil to be pressurized prior to discharge.

As a safety factor to assure sufficient oil delivery under extreme operating conditions, the oil pump is designed to supply a greater amount of oil than is normally needed for adequate lubrication. This requires that an oil pressure relief valve, usually incorporated in the pump, as shown in figures 5-12 and 5-13, be used in the system to prevent excessive oil pressure, especially at high speeds or when the oil is cold. The relief valve has a springloaded ball or plunger that is forced off its seat when the desired pressure, which ranges from 30 to 50 psi, is reached, allowing the excess oil to be delivered

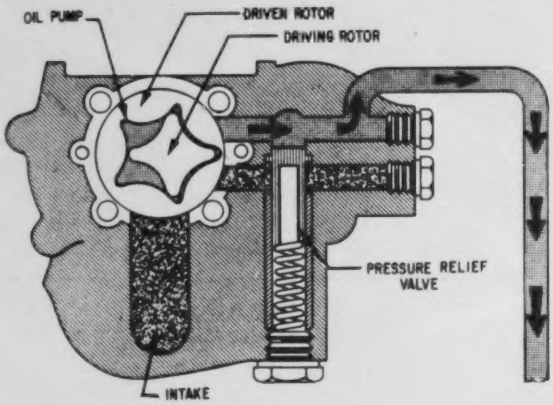

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Figure 5-13.—Rotary oil pump.

to the inlet side of the pump or to return to the crankcase through a drilled passage.

Oil Pressure Gage

The pressure gage is mounted on the instrument panel of the vehicle. Marked off on a dial in psi, the gage indicates how regularly and evenly the oil is being delivered to all vital parts of the engine, and warns of any stoppages in this delivery. Pressure gages may be MECHANICAL or ELECTRICAL. In the mechanical type, the gage on the instrument panel is connected to an oil line tapped into the main oil supply passage leading from the pump. The pressure of the oil in the system acts on a diaphragm within the gage, causing a needle to register on a dial. In the electrical type, the oil pressure operates a device on the engine which signals electrically to the pressure gage which indicates the oil pressure.

Some of the vehicles brought into the shop will not be equipped with an oil pressure gage, but will have electrically operated warning lights on the instrument panel, which flash on and remain lighted to indicate low oil pressures.

Oil Strainers

Most engines use at least one oil strainer or screen in the lubrication system. The strainer must have a mesh suitable for straining out undesirable particles from the oil and yet pass a sufficient quantity of oil to the inlet side of the pump. The strainer is located so that all oil entering the pump from the oil pan must flow through it. Some screen assemblies also incorporate a safety valve which opens in the event the screen becomes clogged, thus bypassing oil to the pump. Strainer assemblies may be either the floating or the fixed type.

The FLOATING STRAINER has a sealed air chamber, is hinged to the oil pump inlet, and floats just below the top of the oil. As the oil level changes, the floating intake will rise or fall accordingly. Thus, all oil taken into the pump comes from the surface. This prevents the pump from drawing oil from the bottom of the oil pan, where dirt, water, and sludge are likely to collect. The strainer screen is held to the float by a holding clip and the up or down movement of the float is limited by stops.

The FIXED STRAINER is simply an inverted funnel-like device, as shown in figure 5-14, placed about 1/2 inch to 1 inch from the bottom of the oil pan. Thus, any sludge or dirt accumulation in the bottom of the pan is prevented from circulating through the system. The assembly is attached solidly to the oil pump in a fixed position.

Oil Filters

The oil cleaner, or filter, is placed in the oil line beyond the pump and is usually mounted on the engine in an accessible location. The average automotive engine uses a single filter while larger engines, especially diesel, use banks of two or more filters.

The filter cleans the oil and removes most of the impurities that were picked up by the oil as it circulated through the engine. The filter is connected so that part of all of the oil passes through it each time the oil is circulated through the engine. Some oil filters have washable filter elements and some have replaceable elements or cartridges, while still others require replacement or the entire assembly.

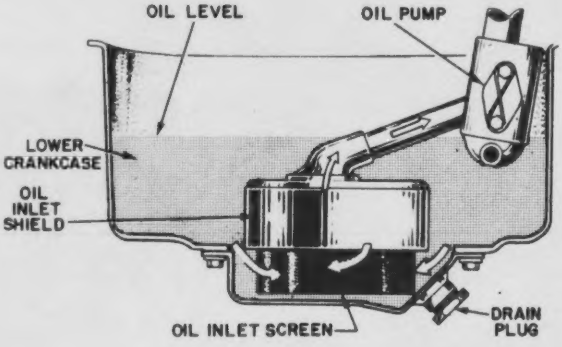

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Figure 5-14.—Fixed oil strainer.

The elements themselves may be either metallic or nonmetallic. The metallic elements are made of bronze and are more or less permanent, since they are washable. Nonmetallic filter elements are composed of paper or a composition of paper and other materials, and must be replaced periodically.

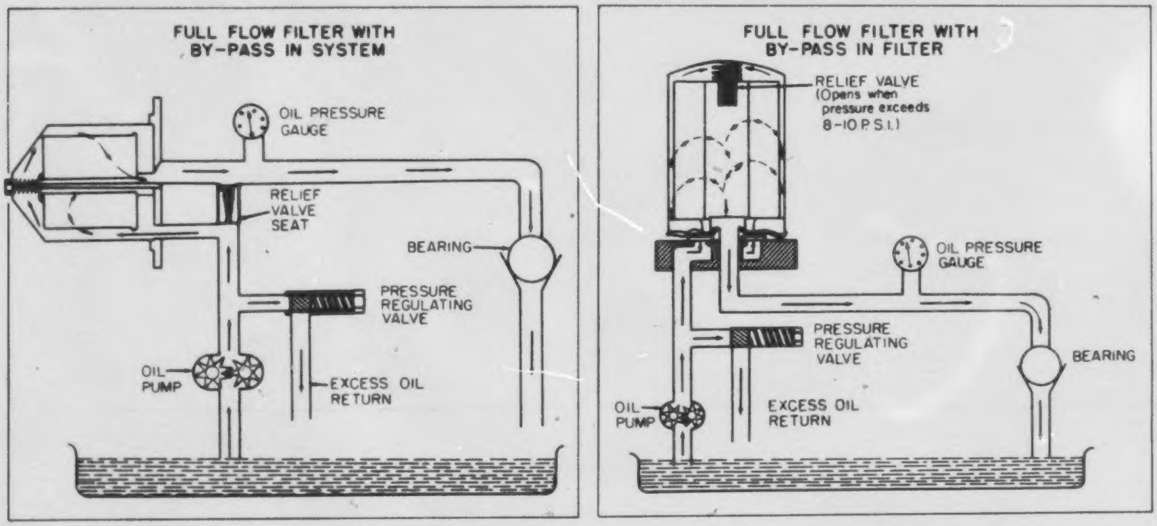
FULL FLOW FILTERS (fig. 5-15) are designed to filter the full oil output of the pump. This type of filter strains all of the oil before it is distributed to the engine.

With the full flow type filter, a relief or bypass valve must be provided to allow the oil to flow around the filter in the event the filter becomes clogged. This valve opens when the back pressure caused by clogging becomes greater than the tension of the valve spring. The engine is thus assured an adequate supply of oil in case of filter failure. The bypass valve is incorporated in the filter assembly or located in the engine block near the filter.

PARTIAL FLOW FILTERS (fig. 5-16) strain only a small amount of the oil being circulated by the pump. The oil from the main oil gallery enters the filter and flows through the filter element. It then passes into the metal perforated collector in the center of the filter. The filtered oil then flows out the outlet, which is restricted to prevent loss of pressure. After passing through the restriction, the oil either returns to the crankcase directly or by way of the timing gears, rocker arms, or other parts needing lubrication. Where the return oil is used [illegible] lubricating such parts, a bypass valve [illegible] used to assure circulation in the event the filter becomes clogged. A drain plug is usually incorporated in the bottom of the filter case for sludge removal.

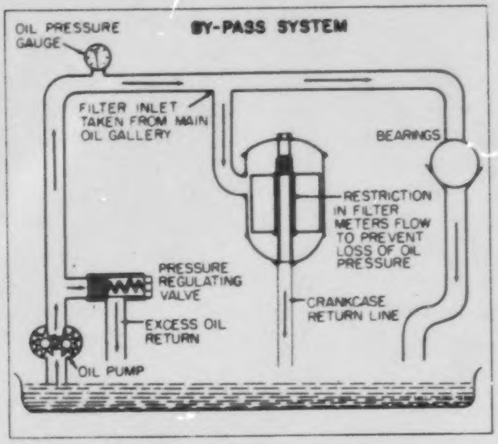
Oil Level Gage

The oil level gage, known also as a dipstick, is usually of the bayonet type. It consists of a long rod or blade that extends into the oil pan. It is marked to show EMPTY, LOW, and FULL, or sometimes just LOW and FULL or FULL and ADD. Readings are taken by pulling the rod out from its normal place in the crankcase, wiping it clean, replacing it, and again removing and noting the height of the oil on the lower or


FULL FLOW FILTER WITH BY-PASS IN SYSTEM
OIL PRESSURE GAUGE
RELIEF VALVE SEAT
BEARING
PRESSURE REGULATING VALVE
OIL PUMP
EXCESS OIL RETURN
FULL FLOW FILTER WITH BY-PASS IN FILTER
RELIEF VALVE (Opens when pressure exceeds 8-10 P.S.I.)
OIL PRESSURE GAUGE
PRESSURE REGULATING VALVE
BEARING
OIL PUMP
EXCESS OIL RETURN

81.388X

Figure 5-15.—Full flow filters.


BY-PASS SYSTEM
OIL PRESSURE GAUGE
FILTER INLET TAKEN FROM MAIN OIL GALLERY
BEARINGS
RESTRICTION IN FILTER METERS FLOW TO PREVENT LOSS OF OIL PRESSURE
PRESSURE REGULATING VALVE
CRANKCASE RETURN LINE
EXCESS OIL RETURN
OIL PUMP

81.387X

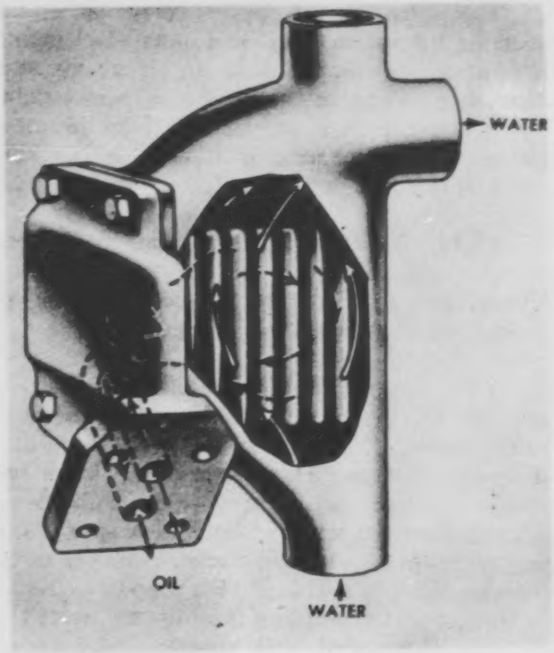
Figure 5-16.—Partial flow filter.

marked end. This should be done with the engine stopped unless the manufacturer recommends otherwise. It is very important that the oil level not drop below the LOW mark or rise above the FULL mark.

Oil Temperature Regulator

The oil temperature regulator, found mostly in diesel engine lubricating systems, prevents the temperature of the oil from rising too high in hot weather. The regulator unit (fig. 5-17), which makes use of the water in the cooling system, is made up of a core and a housing. The core, through which the oil circulates, is exposed to the water which circulates through the housing. As the oil passes through the regulator, it is either cooled or heated, depending on the temperature of the water in the cooling system. From the regulator the oil enters the oil passages that lead to the engine parts.

Some military vehicles use an oil cooler which consists of a radiator through which air is circulated by movement of the vehicle and the cooling fan. This radiator, through which oil passes to and from the oil pan through the engine passages, acts only to cool the oil.


WATER
OIL
WATER

81.116

Figure 5-17.—Oil temperature regulator (cooler).

TYPES OF LUBRICATION SYSTEMS

Now that you are familar with the lubrication system in general, you are ready to study the different methods used to circulate oil through the engine. The systems used to circulate oil are known as splash, combination splash force-feed, force-feed, and full force-feed.

Splash

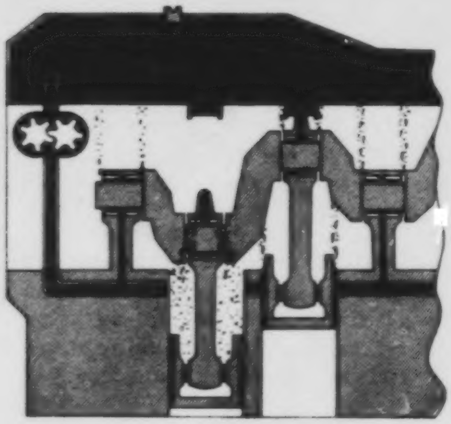
In the splash system, dippers on the connecting rods enter the oil in the crankcase with each revolution of the crankshaft and splash oil to the upper parts of the engine. The oil thus thrown upward in droplets and mist provides lubrication for the valve mechanisms, piston pins, and other moving parts. The splash system is rarely found on modern engines, because its lubricating effect is too uncertain to meet today's heavy operating demands. On a full crankcase it could mean overlubrication and a waste of oil, while on a partly filled crankcase it could cause inadequate lubrication and failure of the engine.

Combination Splash Force-Feed

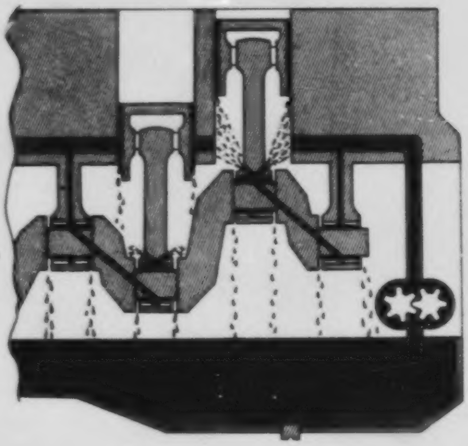
The combination splash force-feed system (fig. 5-18), as the term implies, depends on oil splash and pressure to accomplish engine lubrication. The oil pump forces oil under pressure to the main and camshaft bearings and the valve mechanisms. But the connecting rods, the pistons, piston pins, and cylinder walls are lubricated by dippers splashing oil into the troughs underneath the connecting rod bearing caps. These troughs are kept filled by the oil pump, which delivers the oil through nozzles.

Force-Feed

The force-feed (or pressure-feed) system (fig. 5-19) forces oil from the crankcase to the main bearings, camshaft bearings, and connecting rod bearings. The oil enters a line or a channel from the pump and then flows to the crankshaft bearings, which in turn feed the oil into drilled passages in the crankshaft. From these passages it flows through holes in the connecting rods. The cylinder walls, pistons, and piston pins are lubricated by the oil thrown off from the connecting rods.



81.118
Figure 5-18.—Combination spash force-feed lubrication system.



81.117
Figure 5-19.—Force-feed lubrication system.

Full Force-Feed

In the full force-feed system (fig. 5-20) all bearings, as well as the pistons and piston pins, are lubricated by oil under pressure from the pump. Oil enters the crankshaft oil passages, passes to the connecting rod bearings, enters holes drilled in the connecting rods, goes up through the rod passages to the piston pin bearings, and helps lubricate both the pistons and the cylinder walls.

LUBRICATION SYSTEM MAINTENANCE

As a 3rd or 2nd class mechanic, you will be required to maintain the engine lubrication system. This maintenance normally consists of changing the oil and filters. Occasionally you

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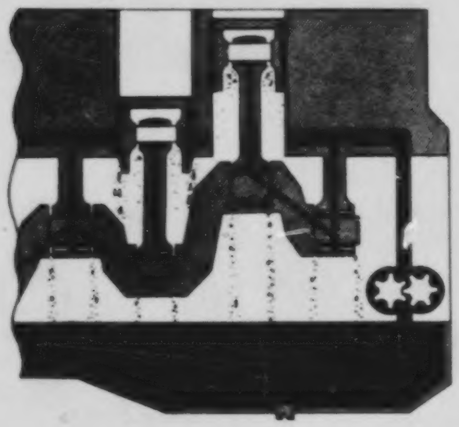

81.119
Figure 5-20.—Full force-feed lubrication system.

might be required to perform such maintenance tasks as replacing lines and fittings, servicing the oil pump and relief valve, and flushing the system. The following discussion provides information which will aid you in carrying out these duties.

Oil and Filter Change

Whenever the engine oil feels gritty when rubbed between your fingers or has no body, it has lost its lubricating qualities and should be changed. In any case, oil and filter changes are made in accordance with PM schedules. On most of your equipment the grade and quantity of the oil to be used will be found on a plate or chart in the cab. The oil should be changed more frequently in cold weather and in vehicles operated under dusty or other very unfavorable conditions. Your chief or leading petty officer will give you specific directions about oil changes on such vehicles.

Drain the oil only after the engine has been run and is warmed up. This warmup period will thin the oil and stir up the sludge and foreign matter in the oil pan. Cold oil is thick and will not drain readily, and foreign matter will tend to stick to the sides of the oil pan when the engine is cold. Usually the filter elements are changed at the time the oil is changed in the crankcase. On new engines it may be changed after the first 500 or 1000 miles; according to the manufacturer's instructions; or according to shop policy. The filter element should be replaced by the type recommended by the manufacturer. Be sure to remove the old gasket and make sure that the new gasket under the cover or in the crankcase is properly fitted.

In replacing the filter element, remove the drain plug from the bottom of the housing. Next, remove the cover by loosening the center bolt or clamp. Now lift out the old element, and wipe the inside of the housing with a clean cloth. Some filter housings do not have drain plugs. Therefore, you must first remove the cover; next remove the filter element and take out the dirty oil with a siphon gun; and then wipe the inside of the housing with a clean lintless cloth. Remove all traces of dirt or lint which remain inside. Install the new element. Finally, replace the drain plug and the cover, using a new gasket, or just the gasket and cover on filter housing without drain plugs.

On the type of filter that does not have a replaceable element, disconnect the oil lines to the old filter, dismount the filter, install the new one, and reconnect the oil lines.

The screw-on type of filter, which is disposable, has an integral gasket. Installation instructions are printed right on the filter or included in the carton. The greatest danger with this filter is installing it too tight.

After filling the oil pan with new oil, recheck the oil level to be certain that the oil column reaches the FULL marking on the dipstick. Then run the engine for a few minutes to insure no leaks exists, particularly around the oil filter housing and the oil drain plug. Get into the habit of looking at the ground or pavement over which a vehicle has been parked, for any oil spots that may indicate leakage.

Ordinarily, low oil pressure readings may be due to thin or diluted oil, excessive heating, an improper grade of oil, or a low oil level in the oil pan. If no pressure shows, or if the pressure is erratic even after replacing the old oil with new of the proper grade, a defective oil gage may be the cause. If so, it is usually better to replace the entire gage unit than attempt repairs.

Persistent low pressure readings or a zero reading could point to trouble in the oil pump. While a complete failure of the oil pump is rare, any wear of its moving parts is likely to impair its efficiency.

High pressure readings may be observed while the engine is warming up in cold weather, before the oil has reached operating temperature. After a brief warmup period the gage indicator should return to normal. A persistent high pressure points to the possibility of a clogged oil line or a poorly operating pressure relief valve.

Servicing Oil Lines, Fittings, and Strainers

Oil lines and fittings must be maintained so as to correct leakage and loss of oil pressure. Where lines are leaking at connections, correction can often be made by tightening the fittings or couplings, being sure to use two wrenches as with fuel lines. Leaks in a line, whether flexible or rigid, require replacement of the line. Lines showing evidence of cracks or deterioration should also be replaced.

It is most essential that the oil strainer be kept clean to permit free flow of oil to the pump. The need for cleaning is sometimes indicated by lowered oil pressure. When cleaning a strainer, you should note any deposits, since they may furnish valuable clues as to the engine condition. Metal bearing particles, for example, indicate deterioration of some bearing or journal. To service the strainer, remove the oil pan; clean the fine-mesh bronze strainer using solvent and a brush, and then dry with compressed air. If the screen is damaged, it must be replaced. In the case of the floating-type strainer, you should also make sure it is not binding.

Oil Pump and Relief Valve

Service on oil pumps and most relief valves is rather limited, since they are relatively trouble-free. An oil pump will often still be operating effectively when the vehicle is ready for salvage. Thus, when low oil pressure or lack of oil pressure develops, you should not immediately assume that the pump is at fault. More commonly, the trouble is caused by an inaccurate or inoperative oil pressure gage, oil of too low viscosity, high engine operating temperatures, cracked or clogged lines or screens, or a malfunctioning relief valve. However, where the oil pump is found to be at fault, it will be necessary to remove it and either repair or replace it. Most often the pump is replaced with a new or factory rebuilt pump.

To replace the oil pump, it is first necessary to determine its location and method of drive. The pump may be located either in the oil pan or outside on the lower part of the crankcase, and driven either directly by the camshaft or indirectly via the distributor shaft. Those driven indirectly from the distributor shaft are easily replaced regardless or their location. The directly driven pumps, on the other hand, pose a problem, since they usually drive the distributor. The procedure for removing and replacing a pump of this type is outlined in the vehicle's maintenance manuals. The quickest way to find out how an engine's pump is driven is to check the manual. The next best and most expedient method is to lift the distributor and look at its shaft. If it has a gear, it drives the pump, and removal of the pump will not affect timing. On the other hand, if it has a slot or driving lug instead of a gear, it's driven by the pump shaft. The general procedure in the latter case is to remove the distributor cap and crank the engine until the rotor is aimed at No. 1 cylinder. Aline the timing marks (flywheel or crankshaft front pulley). Then proceed with the removal of the oil pump. In replacing the pump, simply index its drive gear so that the clutch or driving lug on the distributor and pump shafts will aline and mesh without movement of the distributor shaft (or at least with a minimum of movement). If it moves, the ignition must be retimed. Under no circumstances should you ever drive or force an oil pump into or out of place. Instead, find out what is holding it; a safety pin or burr on a casting are the most frequent causes. Also, when replacing either the gear or rotary pump, you should always fill the pumping chamber with oil. The pumps need that oil to effect a positive seal and to prime them. A new gasket should be used and the retaining screws tightened as specified.

Cleaning and adjusting is all that is usually required on the relief valve, although some types are nonadjustable. A relief valve is cleaned to prevent or to cure sticking. The plunger or valve must be free to move one way or the other under pressure from the oil or spring. A relief valve may be adjusted in one of two ways. It may be done with an adjusting screw (having a jam or locknut) which either adds or relieves pressure on the spring, or it may be done by adding or removing shims or by replacing the spring with one of a different strength. In either case, you should follow the manufacturer's recommendations.

Flushing the System

Flushing the lubrication system is designed to keep an engine clean, but can have an undesirable effect if used on an old engine which has never been flushed. For example, let us compare two jeeps (A & B) that have accumulated 50,000 miles each. Let's assume that jeep A has had an engine flush every other oil change while jeep B has never had one. If you give both jeeps a good flushing now, jeep B will probably develop what is known as a "loose engine." The engine may rattle, blow smoke and leak oil. The reason for this is that jeep A had most of its sludge and carbon removed as it accumulated, leaving the parts clean and free to operate. Jeep B, on the other hand, was allowed to accumulate all this sludge and carbon. This accumulation wore metal away on rings, valve stems, and so on, and literally replaced the worn away metal with sludge and carbon. When you flushed the engine on jeep B, most of the sludge and carbon buildup was removed, leaving excessive clearance between parts. So remember, periodic flushing will aid in prolonging engine life.

The object of flushing is to remove as much carbon, sludge, metal particles, dirt, and so on, as possible. Don't expect to get it all; the most you do is get the bulk of it. Before attempting to flush an engine, remove the filter element, clean the filter case thoroughly, and reinstall the cover. In the case of some of the modern engines using throwaway filter units, you can use an adapter cover in place of the filter or burn out a discarded filter unit (removing all the filter element and cleaning out the ashes) and use the case. Another alternative is to use a new throwaway cartridge for flushing and then replace it before filling the crankcase with new oil. This is somewhat expensive but is quite effective.

The next preparatory to flushing is to drain the engine oil, making sure the engine is hot, like you do when making a regular oil change. Then replace the drain plug and mix and pour the flushing compound into the engine. The most common flushing compounds consist of a regular lubricating oil mixed with an equal quantity of either diesel fuel (No. 1 or 2), kerosene, or solvent. Do NOT use straight diesel fuel, kerosene, or solvent to flush an engine.

The compound must be thoroughly mixed in a container before it is poured into the engine. The crankcase is normally overfilled by 51 to 25 percent. For example, a 6-quart system should have about 8 quarts of compound used for flushing. Flushing may also be accomplished with additives. To use these, you perform a regular oil change, refilling with a lightweight oil and then pouring in the additive compound. Normally, 1 quart of compound is added per 5 quarts of crankcase capacity. This varies, so follow the instructions provided. For example, one manufacturer recommends flushing only with a good grade of SAE 10W engine oil.

Proceed by starting the engine and operating at a fast idle for from 5 to 20 minutes. With the

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lighter oil, the engine will sound noisier than usual. While the engine is running, you should constantly monitor or watch the oil pressure gage. There will be a noticeable drop in oil pressure. However, if there is a considerable drop in pressure, immediately stop the engine. By the same token, if there is a sudden and marked increase in pressure, stop the engine, since this indicates clogging of an oil line. This would require cleaning all the oil passages.

Always check with your supervisor about whether an engine needs flushing or not.

CHAPTER 6

AUTOMOTIVE ELECTRICITY: PART I

The electrical systems on equipment used by the Navy are designed to perform a variety of functions. Some electrical systems may have only one circuit while the more complex ones could contain the five circuits illustrated in figure 6-1. In this chapter we will discuss the charging circuit components in detail. The remaining circuits illustrated in figure 6-1 will be discussed in chapter 7.

To understand the electrical equipment described in this training manual, you must be familiar with the fundamentals of magnetism and the flow of current. Chapter 2 of *Basic Electricity*, NAVPERS 10086-B, contains a detailed explanation of electrical theory. Only a brief review of some of the principles of electricity will be given in this chapter so that you may have a better understanding of how and why automotive electrical units function the way they do. Unless you have a clear understanding of the fundamentals of electricity, you will find it difficult to understand and service the various electrical units in this chapter and the one which follows.

ELECTRIC CURRENT

Early scientists assumed the direction of flow of an electric current to be from a positively charged terminal to a negatively charged terminal.

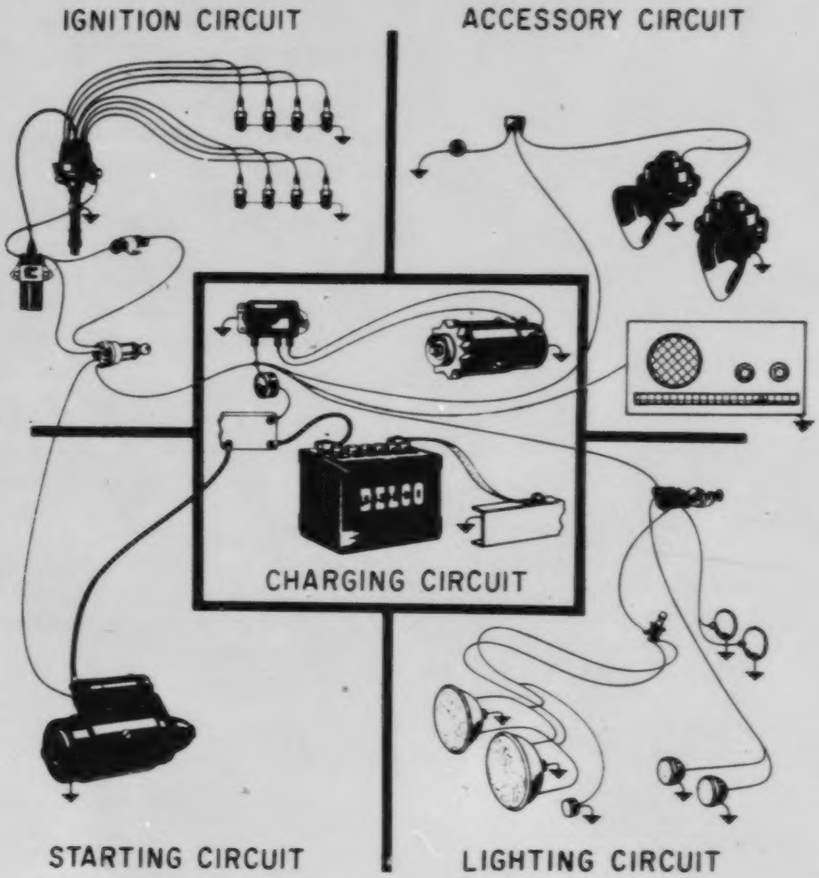
The present day theory is referred to as the ELECTRON THEORY. According to the electron theory, electric current flow is a movement of electrons within a conductor moving from the negative to the positive terminal of an electrical circuit. Thus, when we talk of electric current, we mean electrons in motion.

When electrons flow in one direction only, the current is called DIRECT CURRENT (d-c). A direct current is the movement of free electrons from atom to atom along the conductor. The electrons flow out of the negative terminal of the source, through the load, and back to the positive terminal. The circuit is completed through the source, and the direction of current is always one way in all parts of the circuit.

An ALTERNATING CURRENT (a-c) consists of electrons that move first in one direction and then in the other. This may sound like a contradiction of the electron theory. However, in alternating current, the positive terminal and the negative terminal of the source actually change polarity as the direction of the electron flow changes. In standard 60-cycle house current, for instance, the positive and negative terminals of the source will change polarity 60 times in 1 second.

CONDUCTORS

Conductors permit the motion of a large number of electrons. Copper is a good conductor because it has many free electrons. Electrical energy is transferred through conductors by electrons that are freed from their orbits and travel from atom to atom inside the conductor. Each electron moves a very short distance to a nearby atom, where it replaces one or more electrons by forcing them out of their orbits. The replaced electrons repeat the process on other nearby atoms until the electrons are in motion throughout the entire length of the



81.120

Figure 6-1.—Electrical circuits.

conductor. The greater the number of electrons that can be made to move in a material under the application of a given force, the better are the conductive qualities of that material. Silver, copper, aluminum, zinc, brass, and iron are all good conductors of electrons, and therefore of electricity.

INSULATORS

In contrast to good conductors, some substances, such as rubber, glass, and dry wood have very few free electrons. In these materials much energy must be spent to set the free electrons in motion. Materials that do not have many free electrons are called poor conductors, nonconductors, or insulators. Actually, there is no sharp line between conductors and insulators, since electron motion is known to exist to some extent in all matter. Electricians simply use the best conductors to carry current where it is wanted and the poorest conductors to keep current from unwanted places.

AMPERAGE AND VOLTAGE

Current flow, or electron flow, is measured in amperes. While we normally consider that one ampere is a rather small current of electricity (it is about what a 100-watt light bulb would draw), it is actually a tremendous flow of electrons. More than 6 billion electrons a second are required to make up one ampere.

Before an electric current can flow through a wire there must be a source of electric "pressure," just as you must have a pump to build up water pressure before water will flow through a pipe. This electric pressure is known as ELECTROMOTIVE FORCE (emf) or voltage. This force may be supplied by a generator or storage battery.

The higher the voltage goes, the greater the electron imbalance becomes within the current. The greater this electron imbalance, the harder the push on the electrons (more electrons repelling each other) and the greater the current of electrons in the circuit. When there are many electrons concentrated at the negative terminal of a generator (with corresponding lack of electrons at the positive terminal), there is a much stronger repelling force on the electrons and, consequently, many more electrons moving in the wire. This is exactly the same as saying that the higher the voltage, the more electric current will flow in a circuit, all other things, such as resistance, being equal.

RESISTANCE

Even though a copper wire will conduct electricity with relative ease, it still offers resistance to the flow. It takes force (or voltage) to move the electrons along the wire. This resistance to electron (or current) flow is expressed in ohms. The resistance of a wire varies according to its length, diameter, composition, and temperature.

Many electrical troubles on automotive equipment result from increased resistance in circuits due to bad connections, deteriorated wiring, dirty or burned contacts in switches, and so forth. With any of these conditions, the resistance of the circuit goes up and the ampere flow through that circuit goes down. Bad contact points in the ignition circuit will reduce current flow in the circuit and cause weak sparks at the spark plugs.

If the resistance stays the same but the voltage increases, the amperage also increases. This is a condition that might occur if a generator voltage regulator became defective. In such a case, there would be nothing to hold the generator voltage within limits, and the voltage might increase excessively. This would force excessive amounts of current through various circuits and cause serious damage. If too much current were to go through the light bulb filaments, for example, the filaments would overheat and burn out. Also, other electrical devices probably would be damaged.

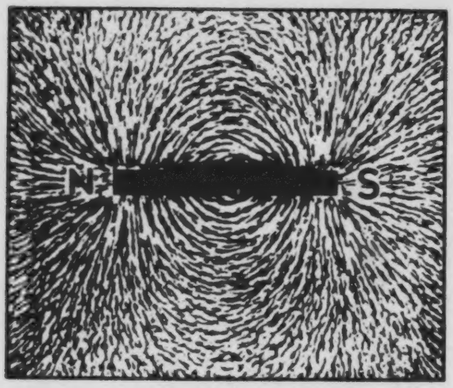
On the other hand, if the voltage is reduced, the amount of current flowing in a circuit will also be reduced if the resistance stays the same. For example, with a rundown storage battery, battery voltage will drop excessively with a heavy discharge. When you try to start an engine with a rundown storage battery, the voltage will drop so low that it cannot push enough current through the cranking motor for effective starting of the engine.

MAGNETISM

There are many facts relating to magnetic forces and many applications of magnetic principles which are responsible for the improvements made in electrical systems. Without the effects of magnetism, there would be no generators for charging batteries or motors for starting engines.

MAGNETIC FIELD

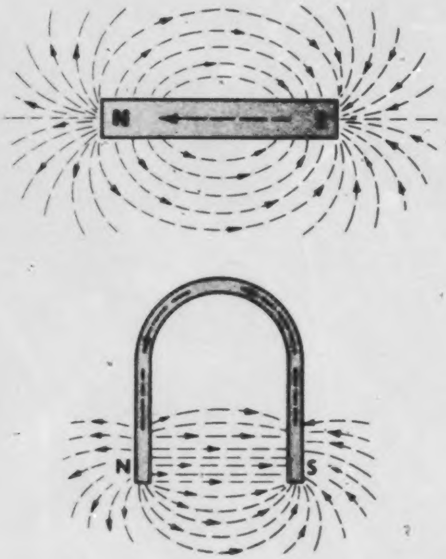
The property or condition of space around a magnet is called a magnetic field. Within the magnetic field there is a force exerted upon any piece of magnetic material that is placed in proximity to the magnet. If you were to place a piece of glass on top of a bar magnet, then sprinkle iron filings on the glass, you would see that the filings would be arranged in curved lines. (See fig. 6-2.) These curved lines, extending from the two poles of the magnet (north and south), follow the MAGNETIC LINES OF FORCE surrounding the magnet.



41.4(27B)
Figure 6-2.—Magnetic lines of force of a bar magnet as shown by iron filings.

This behavior is characteristic of all types of magnets. The paths through which these lines of force flow are known as magnetic circuits or magnetic lines of force.

The magnetic fields of a bar and of a horseshoe magnet are shown in figure 6-3. In each case notice how the lines of force curve and pass from the north to the south pole.

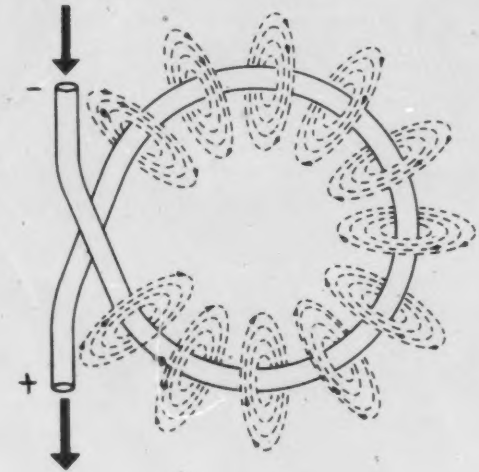


41.5
Figure 6-3.—Magnetic fields of a bar and horseshoe magnet.

When two unlike magnetic poles are brought together, they attract. But when like magnetic poles are brought together, they repel. Other important characteristics of magnetic lines of force are that they cannot be insulated, and they will never cross each other. They cannot be seen or felt, but they are ever present.

ELECTROMAGNETISM

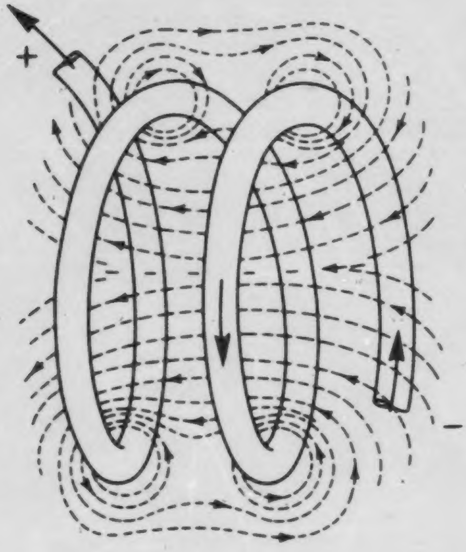
An electric current always produces a magnetic field. The magnetic field produced by current flowing in a single loop of wire is shown in figure 6-4. In a straight wire the magnetic lines of force merely circle the wire, but in figure 6-4 they must follow the curve of the wire. If two loops are made in the conductor, the lines of force will circle the two loops (fig. 6-5). In the area between the adjacent loops, the magnetic lines are going in opposite directions. In such a case, since they are of the same strength (from the same amount of current traveling in both loops), they cancel each other out. The lines of force circle the two loops almost as though they were a single loop.



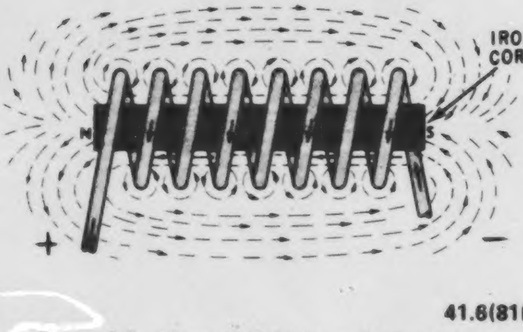
81.122
Figure 6-4.—Magnetic field in a loop of wire carrying current.

However, the lines of force will be twice as strong since the lines of force of the two loops combine.

When many loops of wire are formed into a coil as shown in figure 6-6, the lines of force of all loops combine into a pattern that greatly resembles the magnetic field surrounding a bar magnet. Fixing an iron core in the coil increases the intensity of this magnetic force. Such a configuration is called an electromagnet.



81.123
Figure 6-5.—Magnetic field in two adjoining loops of wire.



41.6(81D)
Figure 6-6.—Magnetic field in an electromagnet.

The field coils of generators and cranking motors, the coils in electric gages, even the windings in a motor armature can be considered to be electromagnets. All of these produce magnetism by electrical means.

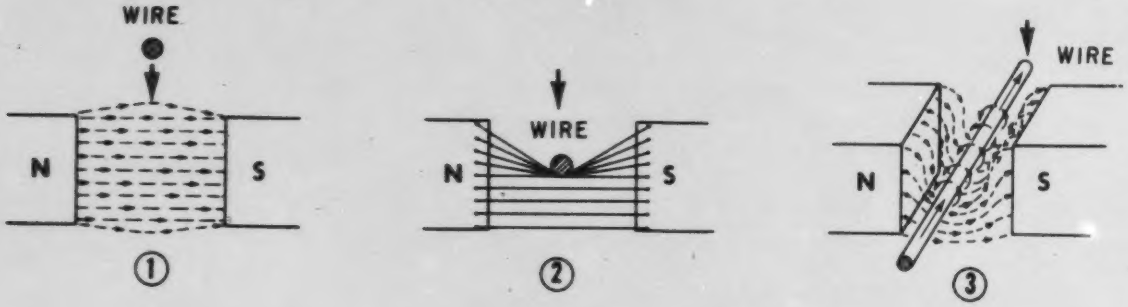
ELECTROMAGNETIC INDUCTION

Current can be induced to flow in a conductor if it is moved through a magnetic field. In figure 6-7, the wire is moved downward through the magnetic field between the two magnetic poles. As it moves downward, cutting lines of force, current is induced in it. The reason for this is that the lines of force resist cutting, and tend to wrap around the core as shown. With lines of force wrapping around the wire, current is induced. The wire movement through the magnetic field produces a magnetic "whirl" around the wire, which pushes the electrons along the wire.

If the wire is held stationary and the magnetic field is moved, the effect is the same. All that is required is that there be relative movement between the conductor and the magnetic lines of force to produce enough voltage to move the electrons along the conductor.

The magnetic field can be moved by moving the magnet. Or, if the magnetic field is from an electromagnet, it can be moved by starting and stopping the current flow in the electromagnet. Suppose you had an electromagnet such as the one shown in figure 6-6, and held a wire close to it. When you connect the electromagnet to a battery, current will start to flow through it. This current, as it flows, builds up a magnetic field. This magnetic field might be considered to expand and move out from the electromagnet. As the lines of force move out, they will be cut by the wire. This wire will therefore have current induced in it. If the electromagnet is disconnected from the battery, these lines of force will disappear and current will stop flowing in the wire.

It can be seen now that current can be induced in a wire by three methods: (1) the wire


WIRE
N
S
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WIRE
N
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②
WIRE
N
S
③

81.124

Figure 6-7.—Current induced by electromagnetic induction.

can be moved through the stationary magnetic field (the principle applied in a d-c generator, (2) the wire can be held stationary and the magnet can be moved so the field is carried past the wire (the principle applied in an a-c generator), or (3) the wire and electromagnet can both be held stationary and the current turned on and off to cause the magnetic field to build up and collapse so that the magnetic field moves one way or the other across the wire (the principle applied in an ignition coil).

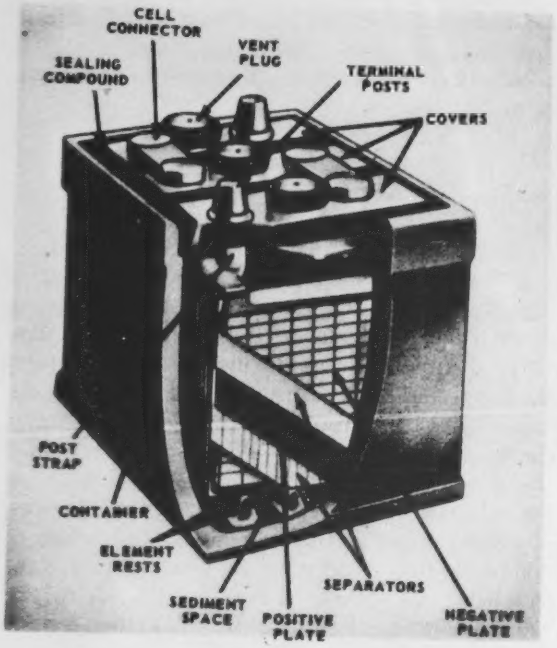
STORAGE BATTERY

The storage battery is the heart of the charging circuit. The type used in automotive, construction, and weight-handling equipment is a lead-acid cell-type battery. It is not a storage tank for electricity but actually stores energy in a chemical form. The battery acts as a stabilizer to the voltage of the electrical system and may, for a limited time, furnish current when the electrical demands of the vehicle exceed the generator output.

Active materials within the battery react chemically to produce a flow of direct current whenever lights, cranking motor, or other current consuming devices are connected to the battery posts. This current is produced by chemical reaction between the active materials of the plates and the sulfuric acid of the electrolyte.

BATTERY CONSTRUCTION

A typical lead-acid storage battery is shown in figure 6-8. Like most batteries it consists of a molded container with individual cell compartments, cell elements, cell connectors, cell covers, terminal posts, and vented filler caps.


CELL CONNECTOR
VENT PLUG
SEALING COMPOUND
TERMINAL POSTS
COVERS
POST STRAP
CONTAINER
ELEMENT RESTS
SEDIMENT SPACE
POSITIVE PLATE
SEPARATORS
NEGATIVE PLATE

81.125(81C)

Figure 6-8.—Cell construction of a storage battery.

The container is made of molded hard rubber, plastic, or bituminous material. It must withstand shock and vibration as well as the heat of the engine compartment. Each cell compartment has rests to support the elements and space for an adequate supply of electrolyte. An area between the element rests allows for any material from the elements to settle without contacting the elements and causing an internal short.

The cell elements contain two kinds of lead plates, known as positive and negative. These plates are insulated from each other by suitable separators made of microporous, nonconductor material (usually porous rubber or spun glass) and are submerged in a sulfuric acid solution (electrolyte).

The newer designs of batteries have a single cover that extends over all cells. In many of the batteries only the filler caps and the terminal posts protrude from the cover. In other batteries having a single cover, only the filler caps extend above the cover; the terminal posts extend through the side. The latest designs of batteries are the so-called maintenance-free batteries which have no means of checking the electrolyte or adding water.

BATTERY CAPACITY

The capacity of a battery is measured in ampere-hours. The ampere-hour capacity is equal to the product of the current in amperes and the time in hours during which the battery is supplying this current. The ampere-hour capacity varies inversely with the discharge current. The size of a cell is determined generally by its ampere-hour capacity. The capacity of a cell depends upon many factors, the most important of which are (1) the area of the plates in contact with the electrolyte; (2) the quantity and specific gravity of the electrolyte; (3) the type of separators; (4) the general condition of the battery (degree of sulfating, plates buckled, separators warped, sediment in bottom of cells, and so forth); and (5) the final limiting voltage.

BATTERY RATINGS

Storage batteries are rated by their VOLTAGE and their AMPERE-HOUR CAPACITY. Each cell has a rated output of approximately 2.0 volts per cell. To get higher voltage from the battery, just connect more cells in series. The common storage battery comes in multiples of 2 volts, such as 6-volt and 12-volt.

Standard automotive batteries have a 20-hour discharge rate. The 20-hour discharge rate of a battery is equal to the constant current in amperes which the battery, starting with an initial electrolyte temperature of 80°F, can supply continuously for 20 hours before the voltage has dropped to the low voltage limit at which the discharge should be stopped. For example, a battery rated by the manufacturer as a 6-volt 120-ampere-hour (Ah) capacity would be discharged at 1/20 of 120 or 6 amperes, until the voltage has dropped to its specified limiting voltage. The number of hours required for the discharge (20) multiplied by the rate of 6 amperes would give you a battery rating of 120 ampere-hours. The voltage and ampere-hour rating of a battery may be stamped on the battery case.

As a storage battery discharges, the sulfuric acid is depleted and the electrolyte is gradually converted into water. This action provides a guide in determining the state of discharge of the lead-acid cell. The electrolyte that is usually placed in a lead-acid battery has a specific gravity of 1.350 or less. Generally, the specific gravity of the electrolyte in Navy portable batteries is adjusted between 1.210 and 1.280, but may be as high as 1.300.

The specific gravity of an electrolyte is actually a measure of its density. The electrolyte becomes less dense as its temperature rises, and more dense as its temperature falls. Thus, a high temperature means a low specific gravity and a low temperature means a high specific gravity. The hydrometer that you use is marked to read specific gravity at only one temperature 80°F. Under normal conditions the temperature of your electrolyte will not vary much from this

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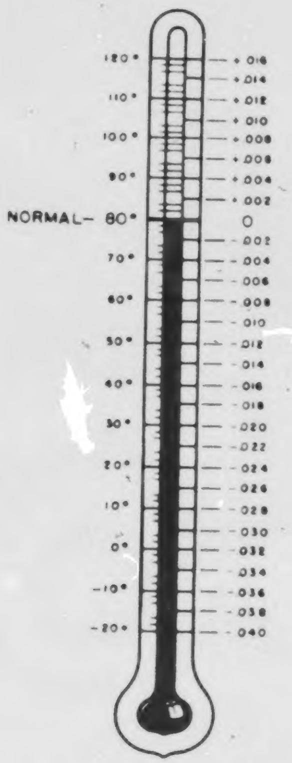
mark. However, large changes in temperature require a correction in your reading.

For EVERY 10-degree change in temperature above 80°F, you must ADD 0.004 to your specific gravity reading. For EVERY 10-degree change in temperature BELOW 80°F, you must SUBTRACT 0.004 from you specific gravity reading. Suppose you have just taken the gravity reading of a cell. The hydrometer reads 1.280. A thermometer in the cell indicates an electrolyte temperature of 60°F. That is a difference of 20 degrees from the normal of 80°F. To get the true gravity reading you must subtract 0.008 from 1.280. Thus the specific gravity of the cell is actually 1.272. A hydrometer conversion chart similar to the one shown in figure 6-9 is usually found on the hydrometer. From it you can obtain the specific gravity correction for temperature changes above or below 80°F.



33.11(81C)

Figure 6-9.—Hydrometer conversion chart.

BATTERY CHARGING

A hydrometer reading below 1.240 specific gravity at 80°F is a danger signal, and if obtained, the battery should be removed and charged. Except in extremely warm climates, never allow the specific gravity to drop below 1.225; in tropical climates this reading indicates a fully charged battery.

Recharge immediately a rundown battery which is brought into the shop. There are several methods for charging batteries; only direct current is used with each method. If only alternating current is available, a rectifier or motor generator must be used to convert to direct current. The two principal methods of charging are (1) constant current, and (2) constant voltage (constant potential). Constant current charging may be used on a single battery or a number of batteries in series. Constant potential charging is used with batteries connected in parallel. (A parallel circuit has more than one path between the two source terminals; a series circuit is a one-path circuit.) You know both methods, although the latter is more often used.

Constant Current Charging

With the constant current method, the battery is connected to a charging device that supplies a steady flow of current. The charging device has a rectifier (a gas-filled bulb or a series of chemical disks), which allows the current to flow only one way; thus, the alternating current is changed into direct current. A rheostat (resistor for regulating current) of some kind is usually built into the charger so that you can adjust the amount of current flow to the battery. Once the rheostat is set, the amount of current remains constant. The usual charging rate is 1 amp per positive plate per cell. Thus, a 21-plate battery (which has 10 positive plates per cell) should have a charging rate no greater than 10 amps. When using this method of charging a battery, you should check the battery frequently, particularly near the end of the charging period. When the battery is gassing freely and the specific gravity remains constant for 2 hours, you can assume that the battery will take no more charge.

The main disadvantage of constant current charging is: THE CHARGING CURRENT REMAINS AT A STEADY VALUE UNLESS YOU CHANGE IT. A battery charged with too high a current rate will overheat and damage the plates, making the battery useless. Do NOT allow the battery temperature to excedd 110° while charging.

Constant Voltage Charging

Constant voltage charging, also known as constant potential charging, is usually done with a motor-generator set. The motor drives a generator (similar to a generator on a vehicle); this generator produces current to charge the battery. The voltage in this type of system is usually held constant. With a constant voltage, the charging rate to a low battery will be high. But as the battery approaches full charge, the opposing voltage of the battery goes up so that it more strongly opposes the charging current. This opposition to the charging current indicates that a smaller charging is needed. As the battery approaches full charge, the charging voltage decreases. This lessens the ability to maintain a charging current to the battery. As a result, the charging current tapers off to a very low value by the time the battery is fully charged. This is the principle of operation of the generator and voltage regulator on a vehicle.

Good Charging Practices

It is easy to connect the battery to the charger, turn the charging current on, and, after a normal charging period, turn the charging current off and remove the battery. Certain precautions, however, are necessary both BEFORE and DURING the charging period. They are:

1. Clean and inspect the battery thoroughly before placing it on charge. Use a solution of baking soda and water for cleaning; and inspect for cracks or breaks in the container. CAUTION: Do not permit the soda and water solution to enter the cells. To do so would neutralize the acid within the electrolyte.

2. Connect the battery to the charger. Be sure the battery terminals are connected properly; connect positive post to positive (+) terminal and negative post to negative (-). terminal. The positive terminals of both battery and charger are marked; those unmarked are negative. The positive post of the battery is, in most cases, slightly larger than the negative post. Insure all connections are tight.

3. See that the vent holes are clear and open. DO NOT REMOVE VENT PLUGS DURING CHARGING. This prevents acid from spraying onto the top of the battery and keeps dirt out of the cells.

4. Check the electrolyte level before charging begins and during charging. Add distilled water if the level of electrolyte is below the top of the plate.

5. Keep the charging room well ventilated. DO NOT SMOKE NEAR BATTERIES BEING CHARGED. Batteries on charge release hydrogen gas. A small spark may cause an explosion.

6. Take frequent hydrometer readings of each cell and record them. You can expect the specific gravity to rise during the charge. If it does not rise, remove the battery and dispose of it as instructed by your chief. Except for minor external repairs, batteries are seldom repaired in the maintenance shop.

7. Keep a close watch for excessive gassing, especially at the very beginning of the charge when using the constant voltage method. Reduce the charging current if excessive gassing occurs. Some gassing is normal and aids in remixing the electrolyte.

8. Do not remove a battery until it has been completely charged.

SELF-DISCHARGE

Discharge takes place in wet, lead-acid storage batteries even when they are not in use. The rate of discharge varies with temperature and specific gravity of the electrolyte. Self-discharge changes the specific gravity of the electrolyte, just as normal discharge does. Inactive charged batteries should be checked periodically and recharged if necessary. This is especially important in cold weather to prevent freezing. At 1.100 specific gravity the electrolyte freezes at 18°F; at 1.220 it freezes at -31 F. A fully charged battery (specific gravity 1.285) will not normally freeze until the temperature reaches approximately -95°F.

PLACING NEW BATTERIES IN SERVICE

New batteries may come to your unit full of electrolyte and fully charged. In this case, all that is necessary is to properly install the batteries in the equipment. Most batteries shipped to SEABEE units, however, are received charged and dry.

Charged and dry batteries will retain their state of full charge indefinitely so long as moisture is not allowed to enter the cells. Therefore, batteries should be stored in a dry place. Moisture and air entering the cells will allow the negative plates to oxidize, thus losing their charge.

To activate a dry battery, remove the restrictors from the vents and remove the vent caps. Then fill all the cells to proper level with electrolyte. Best results are obtained when the temperature of battery and electrolyte is within the range of 60°F to 80°F. Some gassing will occur while you are filling the battery due to the release of carbon dioxide, a product of the drying process, or hydrogen sulfide, caused by the presence of some free sulfur. Therefore, the filling operations should be in a well-ventilated area. These gases and odors are normal and are no cause for alarm.

Approximately 5 minutes after adding electrolyte the battery should be checked for voltage and electrolyte strength. More than 6 volts or more than 12 volts, depending upon the rated voltage of the battery, indicates the battery is ready for service. From 5 to 6 volts or from 10 to 12 volts indicates oxidized negative plates and the battery should be charged before use. Less than 5 or less than 10 volts, depending upon the rated voltage, indicates a bad battery which should not be placed in service.

If, prior to placing the battery in service, the specific gravity, when corrected to 80°F, is more than .030 points lower than it was at the time of initial filling, or if one or more cells gas violently after adding the electrolyte, the battery should be fully charged before use. If the electrolyte reading fails to rise during charging; discard the battery.

Most shops receive ready-mixed electrolyte. Some units may still get concentrated sulfuric acid that must be mixed with distilled water in order to get the proper specific gravity for electrolyte.

MIXING ELECTROLYTE is a dangerous job. You have probably seen holes appear in a uniform for no apparent reason. Later you remembered replacing a storage battery and having carelessly brushed against the battery. When mixing electrolyte, you are handling pure sulfuric acid which can burn clothing quickly and severely burn your hands and face. Always wear rubber gloves, an apron, and goggles for protection against splashes or accidental spilling. If you or one of your men is accidentally burned by acid, keep calm and apply FIRST AID. First, douse the burned area with large amounts of water to remove most of the acid. Then apply a solution of baking soda and water, or ammonia and water, to neutralize any remaining acid. Check in immediately to the nearest dispensary for further treatment.

New batteries may be accompanied by acid of 1.835 specific gravity or electrolyte of 1.400 specific gravity. It will be necessary to dilute these with distilled water to reduce the electrolyte to the proper specific gravity for the climate in which the battery will be used. If distilled water is not available, use rainwater which has been stored in nonmetallic containers. The container in which the acid is diluted should be made of glass, earthenware, or lead. Such a container will resist acid and the heat generated during the mixing operation.

When mixing, NEVER POUR WATER INTO THE ACID. ALWAYS POUR ACID INTO WATER. If water is added to concentrated sulfuric acid, the mixture may explode or splatter and cause severe burns. Pour the acid into the water slowly, stirring gently but thoroughly all the time. Large quantities of acid may require hours for safe dilution.

Figure 6-10 shows you how much water and acid to mix for obtaining a certain specific gravity. For example, an electrolyte of 1.300 specific gravity is produced by mixing five parts of water to two parts of acid, when starting with 1.835 specific gravity acid. If you use 1.400 specific gravity acid, two parts water and five parts acid will give the same results.

Let the mixed electrolyte cool to room temperature before adding it to the battery cells. Hot electrolyte will eat up the cell plates rapidly. To be on the safe side, do not add the electrolyte if its temperature is above 90°F. After filling the battery cells, let the electrolyte cool again because more heat is generated by its contact with the battery plates. Next, take hydrometer readings.

The specific gravity of the electrolyte will correspond quite closely to the values on the mixing chart if the parts of water and acid are mixed correctly.

BATTERY MAINTENANCE AND TESTING

Battery maintenance and testing should always begin with a thorough visual inspection. Look for signs of corrision on or around the battery. Clean the top of the battery with a stiff bristle brush being careful that the particles you brush off do not get on your skin or clothing. Wipe the top of the battery off with a cloth moistened with either ammonia or baking soda dissolved in water; be careful not to allow cleaning solution to enter the battery.

Specific Gravity Desired	Using 1.835 Sp. Gr. Acid		Using 1.400 Sp. Gr. Acid	
	Parts of Water	Parts of Acid	Parts of Water	Parts of Acid
1.400	3	2	--	--
1.345	2	1	1	7
1.300	5	2	2	5
1.290	8	3	9	20
1.275	11	4	11	20
1.250	13	4	3	4
1.225	11	3	1	1
1.200	13	3	13	10

81.368

Figure 6-10.—Electrolyte mixing chart.

Remove the cables and inspect the terminal posts to see if they are deformed or broken. Clean the terminal posts and the inside surfaces of the cable clamps before replacing them on the terminal posts. Inspect the battery holder (cradle) and the battery holddown device. Inspect the battery for a cracked or bulging case and the sealing compound on top of the battery for leaks or cracks.

Remove the vent cap from each cell and check the electrolyte level of the battery. Make sure the vents in the vent caps are free of any obstructions.

The state of charge may be tested with a hydrometer or a "light load tester." The light load or open circuit voltage (OCV) tester is an electrical substitute for the hydrometer and is especially convenient when the electrolyte is low. It is fast and simple to use. It is nothing more than an expanded scale voltmeter with readings from 1.85 volts to 2.25 volts. If a battery has been receiving a charge it will have a surface charge that will cause the cell voltage to be abnormally high. Remove the surface charge by turning on the headlights or some other electrical unit for approximately 1 minute before making a light load test.

If the battery has been on discharge immediately prior to testing, it must be allowed to stand long enough to stabilize before making the test; otherwise, an abnormally low reading will be obtained.

The procedure for testing the battery state of charge will be given on the dial of the tester or in the manufacturer's manual for the tester you have.

The battery load test is recommended by most battery manufactuers. This test indicates how well the battery will perform under normal cranking load conditions. A BATTERY-STARTER tester is the instrument used to make this test. In chapter 7, a brief description of the proper operating procedures for a battery starter tester is given. Familiarize yourself with the proper operating procedures for the type of tester you have available. Improper operation of electrical test equipment may result in serious damage to the test equipment or the unit being tested.

BATTERY SHOP SAFETY

Ventilation of the battery shop is important to your well-being. Make sure there is sufficient ventilation to carry off fumes before they can cause any ill effects. There is also danger of explosion where ventilation is poor. (See figure 6-11.) Do not smoke or cause a spark in the battery room. Never connect or remove batteries while the charger is operating.

If acid splashes in your eyes wash it out with water. Deluge showers and eye-wash fountains should be provided in the immediate vicinity of all battery maintenance and electrolyte handling operations. When these devices are not available, make sure you use care in putting water into the eye. Turn the head to one side in such a position that the water will drain to the side of the head and not toward the other eye.

Burns cause shock and infection. Prompt first aid will lessen shock and help prevent infection. Burns may be caused by contact with acid or with live equipment.

81.525

Figure 6-11.–Unsafe practices in the battery shop are dangerous.

An idea has become widespread that the voltage in a 115-volt line is too low to be harmful. Actually, most of the fatalities that have occurred in the Navy from electrical shock have been due to the victim's contact with a 115-volt line. Even a current as low as 1/5 ampere can be dangerous given the right conditions of defective insulation or dampness. Treat every electrical circuit, even those as low as 35 volts, as a potential source of danger.

If a person comes into contact with a live circuit, immediately deenergize the circuit. If this is not possible, use a wooden stick or pole to free the person from contact with the conductor.

Electric shock usually will stun the nerve center at the base of the brain causing the shock victim to stop breathing. Use any approved mechanical resuscitator to restore breathing, but do not waste time waiting for one. Begin at once to give artificial respiration and continue until medical aid arrives.

GENERATORS

The generator is a machine which applies the principle of electromagnetic induction to convert mechanical energy, supplied by the engine, into electrical energy. The generator restores to the battery the energy that has been used up in cranking the engine. Whether the energy required for the rest of the electrical system is supplied directly by the generator, by the battery, or by a combination of both, depends on the conditions under which the generator is operating.

There are two types of generators used in automotive, construction, and weight handling equipment. The d-c generator supplies electrical energy directly to the battery and/or electrical system through various regulating devices (explained later). The a-c generator (alternator) has the same function as the d-c generator but because d-c only can be used to charge a battery, a component called a rectifier must be employed to convert from alternating to direct current.

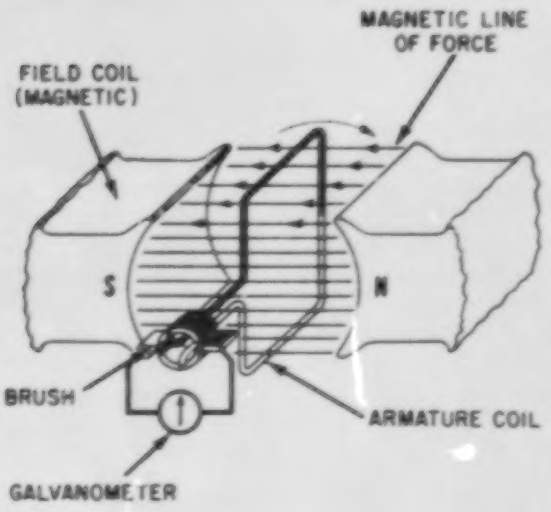


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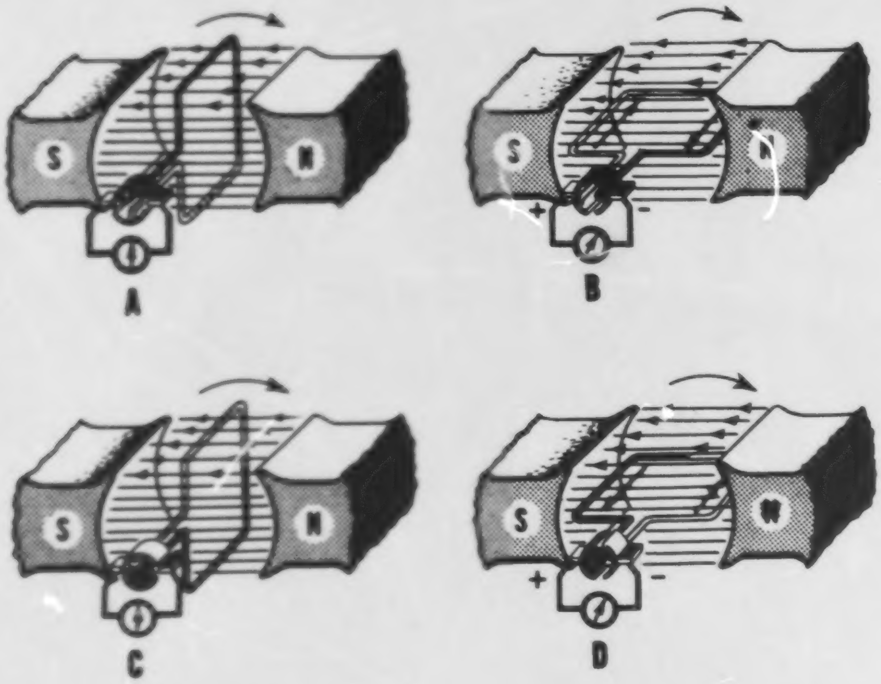
Figure 6-12.—A simple direct-current generator.

DIRECT-CURRENT GENERATOR

The essential parts of a direct-current generator are the armature coil, commutator with brushes, and a stationary field coil. A simple d-c generator is illustrated in figure 6-12. The commutator is a ring split into two segments, which are insulated from each other so that no electrical contact is present between any part of the commutator or armature. The dial and pointer in figures 6-12 and 6-13 represent a galvanometer, an instrument for measuring small amounts of electric current. Notice how the two brushes are mounted on opposite sides of the split ring to permit each brush to be in contact with each segment as the armature turns.

In view A of figure 6-13, the armature is rotating clockwise; the black segment of the



41.10

Figure 6-13.—Generating direct-current electrical energy.

armature is moving toward the north pole, and the white segment is moving toward the south pole. Both segments of the armature are parallel to the lines of force but not cutting across any line; therefore, no voltage is indicated by the galvanometer.

In view B, the armature has rotated 90 degrees. Both segments of the armature are cutting across the lines of force and the voltage is at maximum by the galvanometer.

In views A and C, no lines of force are being crossed; therefore, we have a zero reading on the galvanometer, indicating no voltage. In views B and D, both segments of the armature are cutting across the lines of force, thereby inducing maximum voltage.

In studying figure 6-13, note carefully that in view B, the black brush is in contact with the black segment of the armature and the white brush is in contact with the white segment of the armature; at view C, the black brush is slipping off the black segment onto the white, while at the same instant the white brush is coming into contact with the black segment.

This switching of commutator segments also switches the segments of the armature. In this way the BLACK BRUSH IS ALWAYS IN CONTACT WITH THE SEGMENT MOVING DOWNWARD and the WHITE BRUSH IS ALWAYS IN CONTACT WITH THE SEGMENT OF THE ARMATURE MOVING UPWARD. Though the current actually reverses itself in the loop, it always flows in the same direction (direct current) outside the generator.

Many loops, or turns, of wire are required in the armature for the generator to produce any appreciable amount of current and an even flow of current. Figure 6-14 shows an armature in place in a generator. Notice that many turns are used in the armature windings. The windings are assembled into a soft iron core because the iron is more permeable (conductive of magnetic lines of force) than other substances that could be used. The windings are connected to each other and to the commutator segments in such a way that the current impulses overlap and produce a smooth flow of current. This may be compared to the overlapping of power impulses in an 8-cylinder engine.

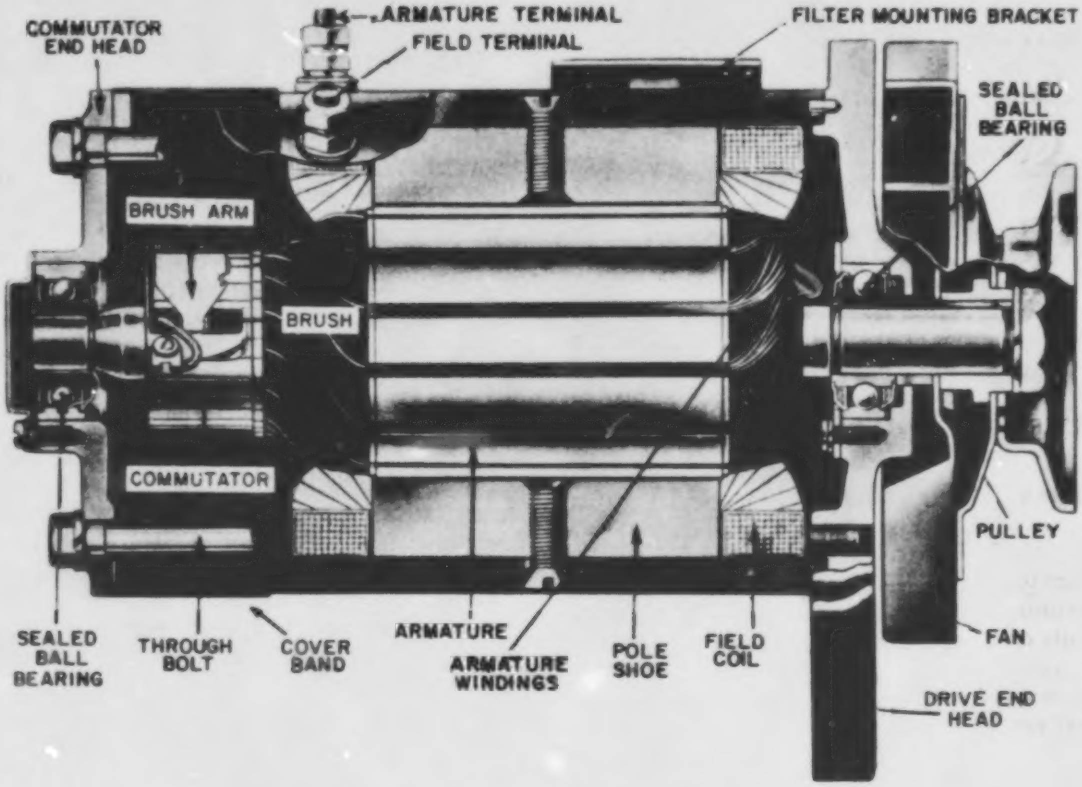
The purpose of the field windings (field coil) (fig. 6-14) is to increase the strength of the magnetic field so that more current will be induced in the armature windings as the armature rotates. There are two types of field circuits, determined by the point at which the field circuit is grounded. One circuit, referred to as the "A" circuit, shunts the field current from insulated brushes through the field winding grounding externally at the regulator. In the other, the "B" circuit, the field current is shunted from the armature series winding in the regulator to the generator field windings, grounding internally within the generator.

The three basic design factors that determine a generator's output are the speed of armature rotation, the number of armature conductors, and the strength of the magnetic field. Any one of these design factors could be used to control the generator voltage and current. However, the simplest method is to determine the strength of the magnetic field and thus limit the voltage and current output of the generator.

Generator Output Control

Since the voltage produced in a d-c generator is dependent upon the amount of current in the fields and the number of lines of force that are cut per second, the voltage will naturally increase with the speed. Regulators are of two types, functioning to regulate either voltage or current. The voltage regulator regulates the voltage in the electric system and prevents excessive voltage, which would cause damage to the electric units and overcharge the battery. The current regulator is a current limiter; it prevents the generator output from increasing beyond the rated output of the generator.

Regulation of voltage only might be satisfactory from the standpoint of the battery; however, if the battery were badly discharged, or if a heavy electrical load were connected, the generator might overload itself to supply the heavy current demand. Therefore, both current


COMMUTATOR END HEAD
ARMATURE TERMINAL
FIELD TERMINAL
FILTER MOUNTING BRACKET
SEALED BALL BEARING
BRUSH ARM
BRUSH
COMMUTATOR
PULLEY
SEALED BALL BEARING
THROUGH BOLT
COVER BAND
ARMATURE
ARMATURE WINDINGS
POLE SHOE
FIELD COIL
FAN
DRIVE END HEAD

75.177

Figure 6-14.—Sectional view of a d-c generator.

and voltage controls are used in a charging system.

In most applications, a regulator assembly consists of a cutout relay, current regulator, and voltage regulator. Each unit contains a separate core, coil and set of contacts. (See fig. 6-15.) The regulator assembly provides full control of the shunt-type generator under all conditions. Either the current regulator or the voltage regulator may be operating at any one time, but in no case do they both operate at the same time.

When the electric load requirements are high and the battery is low, the current regulator will operate to prevent the generator output from exceeding its safe maximum. In this case the voltage is not sufficient to cause the voltage regulator to operate. But if the load requirements are reduced or the battery begins to come up to charge, the line voltage will increase to a value sufficient to cause the voltage regulator to operate. When this happens, the generator output is reduced; it is no longer sufficiently high to cause the current regulator to operate. All regulation is then dependent on the voltage regulator.

Figure 6-16 shows a schematic wiring diagram of a typical charging circuit. In this circuit, two resistances are connected in parallel into the generator-field circuit when the current regulator points open. This provides a low value of resistance, which is sufficient to prevent the

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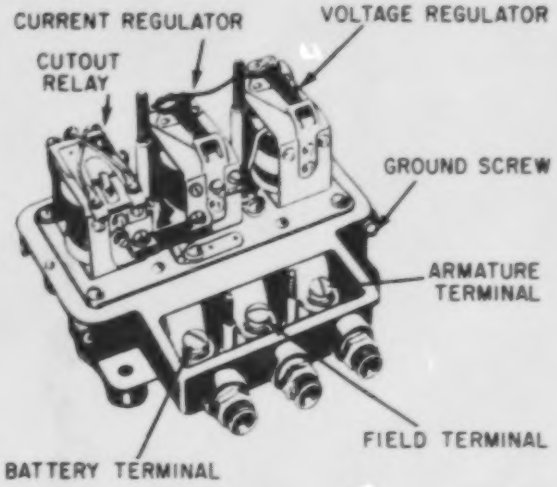

CURRENT REGULATOR
VOLTAGE REGULATOR
CUTOUT RELAY
GROUND SCREW
ARMATURE TERMINAL
FIELD TERMINAL
BATTERY TERMINAL

2.306

Figure 6-15.—Regulator assembly with cover removed.

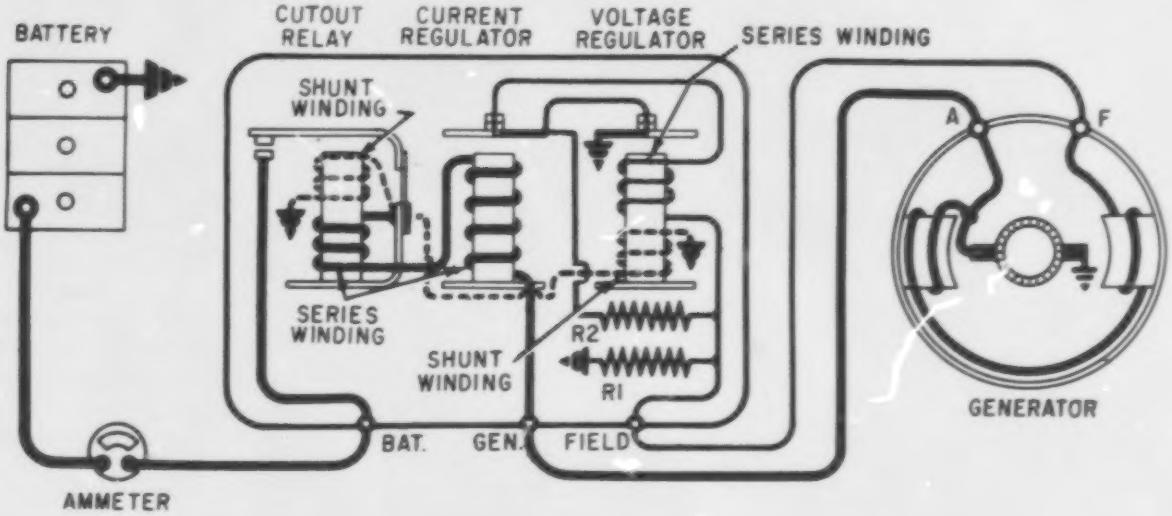
generator output from exceeding its safe maximum. When the voltage regulator contact points open, only one resistance is inserted into the generator-field circuit, and this provides a higher value of resistance. The voltage regulator must employ a higher resistance because it must reduce the generator output as it operates, and it requires more resistance to reduce the output than merely to prevent the output from going beyond the safe maximum of the generator.

For some special applications, you may find a combined current-voltage regulator. In this case both regulators are combined in a single unit. The regulator assembly will consist of two (regulator and circuit breaker) instead of three units.

The regulators just described are known as electromagnetic vibrating-contact regulators. The points on the armatures of the regulators may open and close as many as 300 times in one second in order to achieve the desired regulation.

The TRANSISTOR TYPE REGULATOR is being used in late model equipment. This regulator has no moving parts. It consists of transistors, diodes, condensers, and resistors. Some models have two filter condensers, while others have only one.

Adjustments are provided on some types of regulators and should be made only with the use of the manufacturer's instructions and the recommended testing equipment. TRIAL AND


BATTERY
CUTOUT RELAY
CURRENT REGULATOR
VOLTAGE REGULATOR
SERIES WINDING
SHUNT WINDING
A
F
SERIES WINDING
SHUNT WINDING
R2
RI
GENERATOR
BAT.
GEN.
FIELD
AMMETER

77.154

Figure 6-16.—Schematic wiring diagram of a typical charging circuit.

ERROR METHOD OF REPAIR WILL NOT WORK.

Generator Maintenance

The d-c generator requires periodic cleaning, lubrication, inspection of brushes and commutator, and testing of brush spring tension. In addition, the electrical connections need attention to insure clean, metal-to-metal contact and tightness.

Some generators have hinged cap oilers. Lubricate these with a few drops of medium weight oil at each maintenance cycle. Do not overlubricate, because an excessive amount of oil can get on the commutator and prevent the brushes from functioning properly.

Visually and manually inspect the condition of all starting and charging system cables, clamps, wires, and terminal connections. See that the generator drive pulley is tight on the shaft, and that the drive belt is in good condition and adjusted to proper tension. Also, make sure that the starter, generator, and voltage regulator are securely mounted and have a good ground.

Remove the cover band, on generators so equipped, and inspect the inner surface of the generator cover band for tiny globules of solder. If any solder is found, the generator is producing excessive current and has melted the solder used in connecting the armature wires to the commutator bars. This condition will require removal of the generator to repair or replace the armature.

If no solder is found, inspect the commutator, brushes, and electrical connections. If the commutator is dirty or slightly rough, sand it with number 00 sandpaper or use a special sanding tool. NEVER use emery cloth on a commutator.

To sand the commutator, wrap the end of a flat piece of soft wood with a strip of number 00 sandpaper. Then, with the generator in operation, hold the sandpaper against the commutator and move it back and forth across the commutator. Be sure to hold the sandpaper so that the armature is turning away from rather than toward, the sandpaper to avoid damaging the commutator.

Blow clean compressed air through the interior of the generator to remove any excess dirt and brush particles. Lift brushes in the brush holder to see that they are free to operate and have sufficient tension to prevent arcing and burning of the commutator and brushes. If the brushes are worn down to one-half their original length, replace them.

Some generators in use today are not equipped with cover bands. They may have open slots over the commutator or be entirely sealed. On those with open slots, the commutator can be sanded through the slots but brush removal can only be accomplished by removing the commutator end frame. On sealed units, maintenance can only be performed after disassembly.

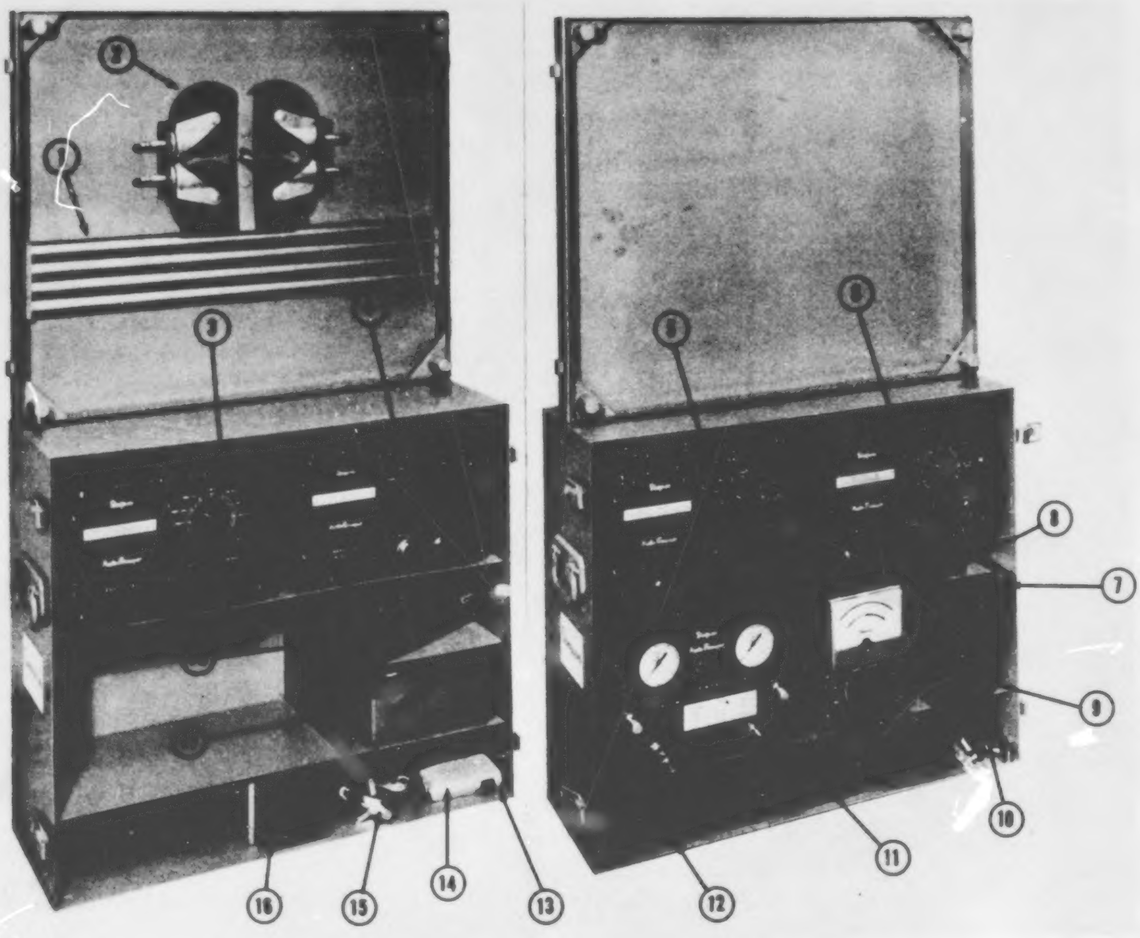
Generator Repair

Automotive generators are disassembled only when major repairs are to be made. Other than cleaning commutators and replacing worn brushes during periodic maintenance checks on the vehicle, automotive generators need few major repairs during normal service life. However, if neglected, generators will develop troubles that cannot be remedied in the field.

Before removing a generator suspected of being faulty, you should check the battery, as discussed earlier, and the generator output.

One piece of test equipment used to test generator output is item 6 in the engine analyzer set shown in figure 6-17. This kit is organic to all NMCB shops. Another piece of test equipment used to test generator output, particularly at permanent shore stations, is the combination voltampere tester shown in figure 6-18.

Should it become necessary for you to use either type of test equipment, refer to the appropriate manufacturer's manual for generator output specifications and proper testing procedures. If the generator is operating properly, and the battery, wiring, and connections are in proper operating condition, a defective regulator is indicated. In most cases, a defective regulator is removed and replaced with



Carrying Case
Assembly No. 1

1. Legs for Stand
2. Castors for Stand
3. Model CMA, Condenser-Magneto Analyzer
4. Model TAT, Timing Advance Tester
5. Model TDI-2, Tachometer-Dwell-Ignition Tester
6. Model CBS, Charging-Battery-Starter Tester
7. Model 260-5, Volt-Ohm-Milliammeter
8. ModelBL-1, Battery Loader
9. Model ADT, Alternator Diode Tester

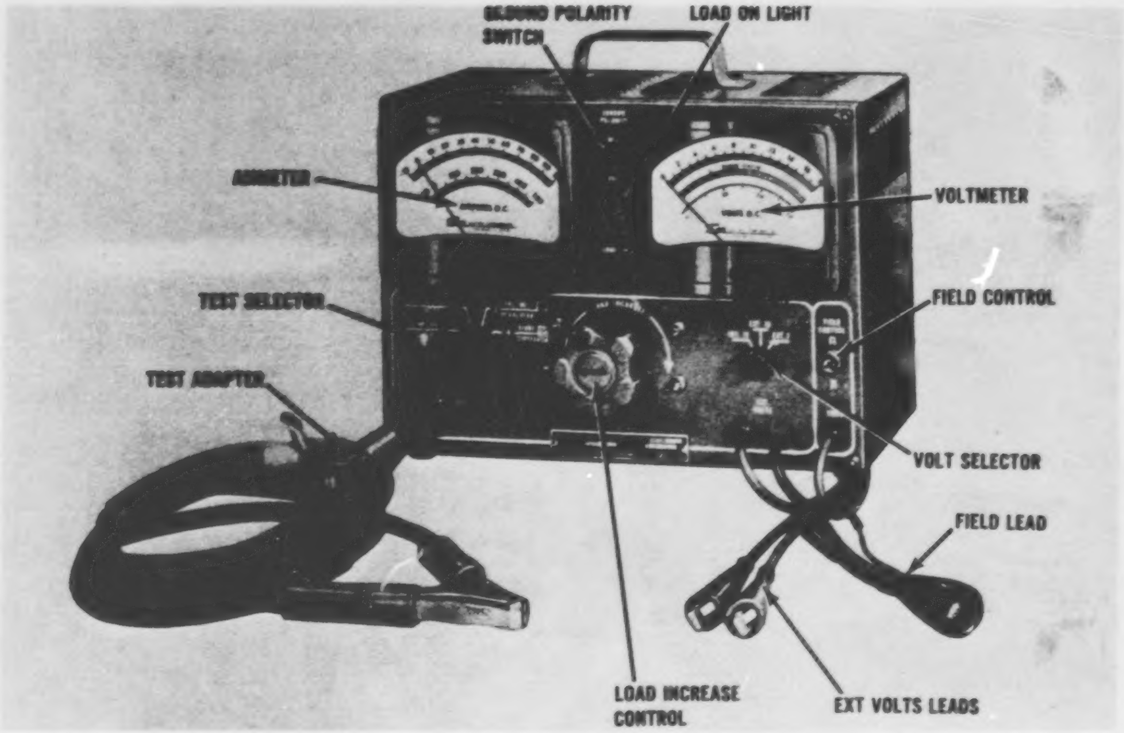
Carrying Case
Assembly No. 2

10. Battery Clamps
11. Model CA, Cylinder Analyzer
12. Carrying Case, Assembly No. 2
13. Carrying Case, Assembly No. 1
14. Model SIS, Starter-Ignition Switch (Handi-Start)
15. Model ATK, Alternator Test Kit
16. Model SPC, Spark Plug Connector Set
17. Model FPT, Fuel Pump Tester
18. Timing Light (Part of Model TAT)

2.415

Figure 6-17.—Engine analyzer set.

173



2.320(2D)

Figure 6-18.—Voltampere tester (VAT).

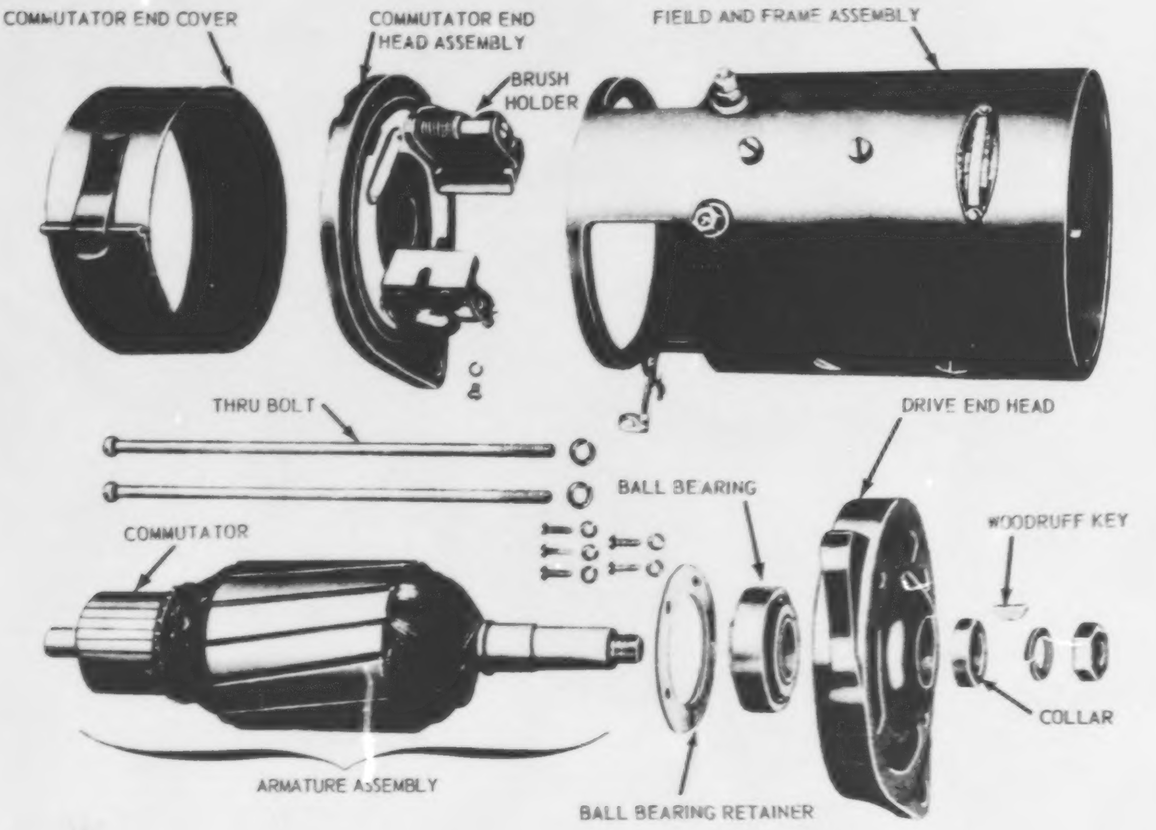
a new one. However, if the generator does not produce the specified amperes at the specified engine revolutions per minute, then it must be removed from the vehicle and repaired.

GENERATOR DISASSEMBLY.—Disassembling the generator is generally limited to removing the commutator end frame and drive end frame so that the armature and bearings can be removed for testing and inspection. A disassembled generator is shown in figure 6-19. The field coils are tested in the frame, and if found defective, the field coil and frame assembly are replaced as a unit.

Although generators differ in size, number and arrangement of brushes, and other construction details, the procedures for disassembling them are similar.

After removing the cover band, carefully examine the generator. Study the brush arrangement to obtain a mental picture of the brush lead connections. Make a pencil sketch so you will know where to replace the wires. Most generators have marks, either scratched or center-punched on the adjacent edges of the frame assembly and end pieces to help in alining these parts during assembly. If these marks are not clearly discernible, make new marks.

It is best to place the generator on end when removing the end frames, because the bearings that center the armature are attached to these frames. This prevents possible damage from the heavy armature dropping down on the field coils. Also, disconnect the field coil leads from the brush assembly before the brush end of the generator is removed. In most cases the brush


COMMUTATOR END COVER
COMMUTATOR END HEAD ASSEMBLY
BRUSH HOLDER
FIELD AND FRAME ASSEMBLY
THRU BOLT
DRIVE END HEAD
BALL BEARING
WOODRUFF KEY
COMMUTATOR
COLLAR
ARMATURE ASSEMBLY
BALL BEARING RETAINER

2.82

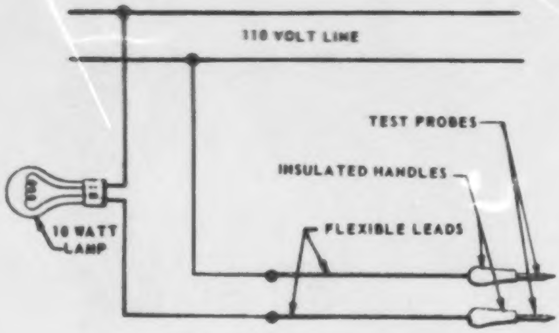
Figure 6-19.–Disassembled view of a two-brush generator.

holders and brushes come away with the commutator end frame. Therefore, in removing the end frame, see that the brushes have been taken from the holders so they are not damaged in sliding off the commutator. NEVER remove the brushes from the holders by pulling on the pigtails without first easing the spring tension against the brushes.

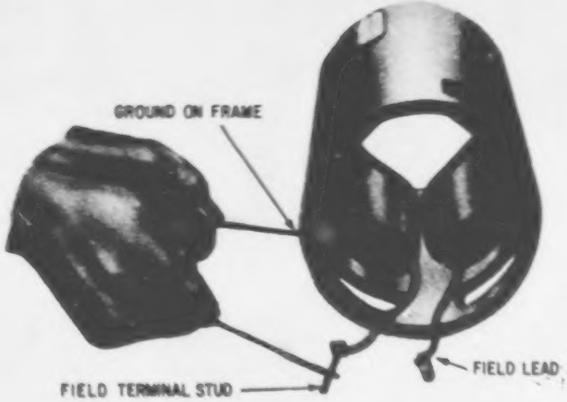
TESTING FIELD COILS.–To test the generator field, you must disconnect the grounded ends from the frame. Place one probe of the test lamp circuit (fig. 6-20) on the field terminal end of the coils and the other probe on the grounded end. If the lamp lights, the field circuit is complete. However, because of the resistance in the field coil wire, it should not burn with normal brilliancy. Normal brilliancy of the test light bulb indicates a possible short circuit between the coils of the field. If the light does not burn, the field is open circuited.

A grounded field coil is found by placing one test probe on the field terminal and the other on the generator frame (fig. 6-21). If the test lamp lights, the field is grounded. The ground may be caused by frayed wires at the coil ends. In most cases, grounds and open circuits in field coils cannot be satisfactorily repaired. The defective field coil must then be replaced.

Tests for grounds, shorts, and open circuits in field coils can also be made with an



2.83
Figure 6-20.—Test probes with test lamp.



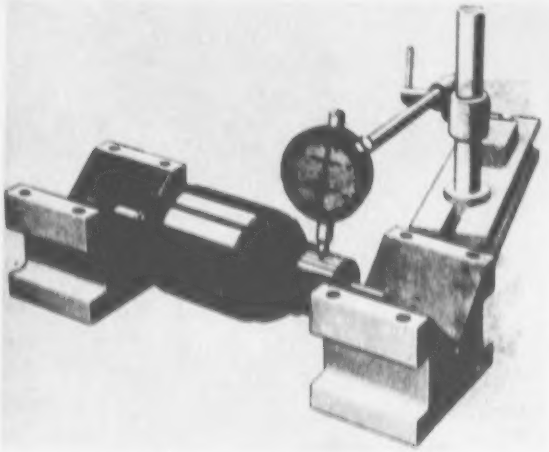
2.84
Figure 6-21.—Testing field coils for grounds.

OHMMETER. The ohmmeter has test probes similar to the test lamp circuit. When these test probes are connected to the field coil ends the ohmmeter will measure the actual resistance of the coil. If the specified resistance of a field coil is given in the manufacturer's manual—also obtained by measuring a new coil—you can compare values obtained through tests. For example, a short-circuited field coil would have practically no resistance and the ohmmeter would register near zero; or the ohmmeter would register excessively high resistance in testing a coil having an open circuit. By following the manufacturer's instructions in using the ohmmeter, field coil tests can be made more quickly and accurately than by using a test lamp circuit.

ARMATURE TEST AND REPAIR.—The armature must be cleaned before it is inspected. Use compressed air to blow off all loose dirt. Then use a cloth dampened in a Navy-approved cleaning fluid to wipe off the armature. Do not allow cleaning fluid to soak into the armature windings.

Inspect the commutator riser bar connections for signs of melted solder and the resulting loosened connections. Small specks of melted solder, even if the connections are tight, indicate that the generator has been overheated from operaring at an overload. In order to eliminate a possible breakdown in the near future, armatures found in this condition should not be reassembled with the generator. Commutator riser bar connections loosened from handling or for other reasons, except overheating, can be soldered. Always use rosin flux in soldering electrical connections. Never use an acid flux as it promotes corrosion.

Check commutator out-of-round by placing the armature in V-blocks and using a dial indicator as shown in figure 6-22. If run-out



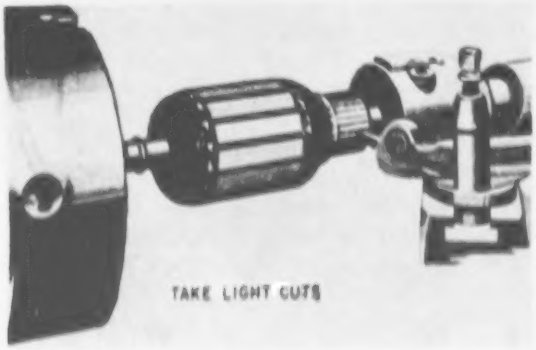
2.85
Figure 6-22.—Measuring commutator out-of-round with dial indicator.

exceeds 0.001 of an inch, or if the commutator is rough or has mica insulation sticking up between segments, the commutator should be turned down.

When it is necessary to turn down the commutator, mount the armature in a lathe, preferably on the armature shaft bearing seats. If that is impossible, the armature may be mounted in the lathe on the armature shaft centers. In turning down a commutator, position the cutting tool on a 90-degree angle with the commutator and approximately 1/32 of an inch below the center line of the armature shaft. (See fig. 6-23.)

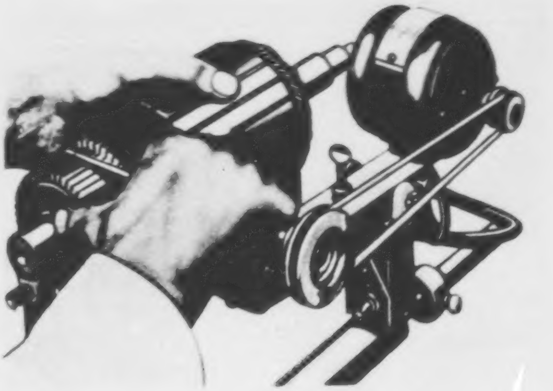
When turning down the commutator, take small cuts and do not remove any more material than is necessary. If you have to turn the commutator down so much that the ends of the commutator segments are less than 1/16 of an inch thick, discard the armature. When the ends of the segments are less than 1/16 of an inch, the commutator bars become so thin that they do not have enough strength to retain their shape.

After cutting the commutator, use 00 sandpaper to smooth any burrs that may be left; then undercut the mica 1/32 of an inch. Mica can be cut by a machine made especially for that purpose (fig. 6-24). If a mica undercutter is not available, you can use handtools and cut the mica as indicated in figure 6-25.



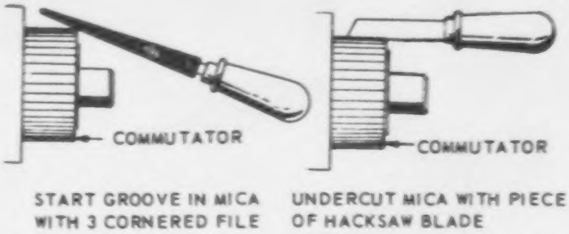
2.86

Figure 6-23.–Turning a commutator down in a lathe.



2.87

Figure 6-24.–Undercutting commutator mica with undercutter.


COMMUTATOR
COMMUTATOR
START GROOVE IN MICA WITH 3 CORNERED FILE
UNDERCUT MICA WITH PIECE OF HACKSAW BLADE

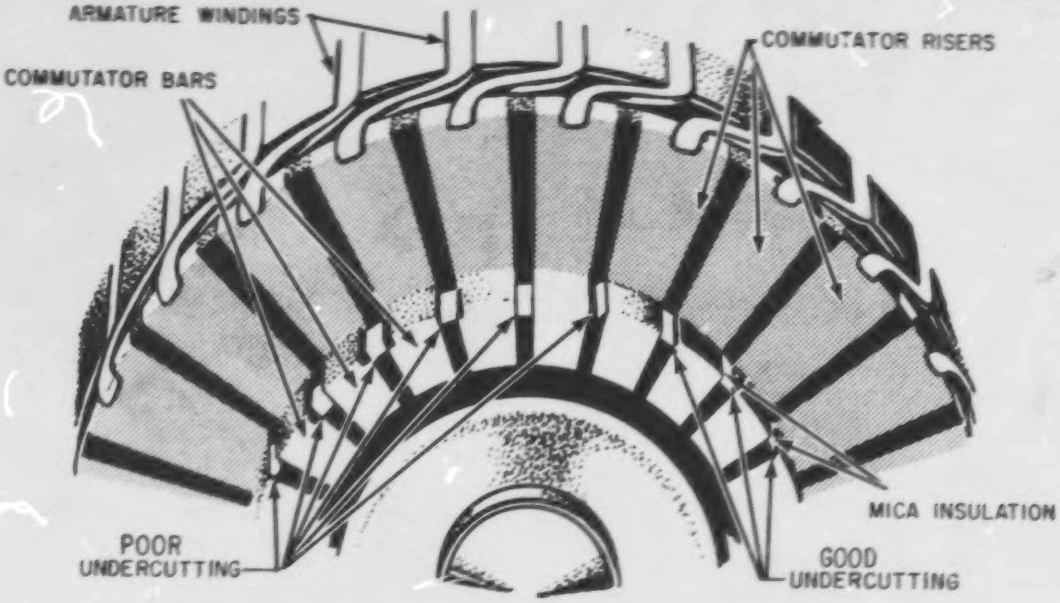
2.88

Figure 6-25.–Undercutting mica with a hacksaw blade.

Use care in undercutting mica so as not to widen commutator slots by removing metal from bars. Do not leave a thin edge of mica next to the bars. Figure 6-26 shows examples of good and poor undercutting.

There are two practical tests for locating shorts, opens, and grounds in armatures: the growler test, and the bar-to-bar test.

To test for short circuits, place the armature on the V-block of the growler and turn on the current. With a thin metal strip (hacksaw blade



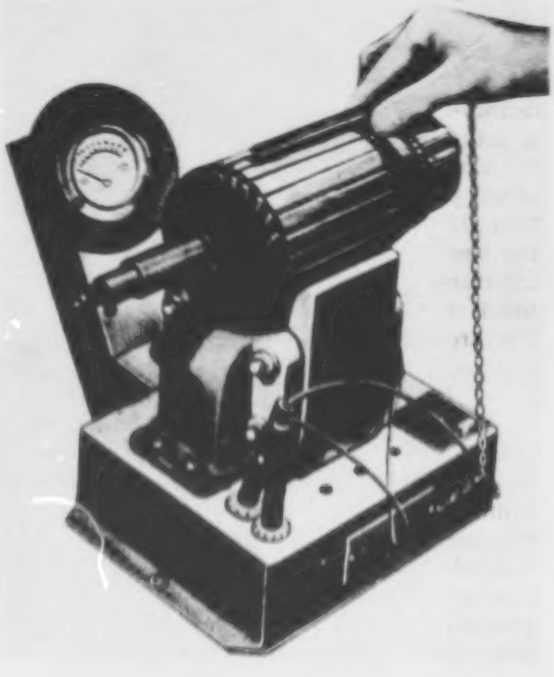
2.89

Figure 6-26.—Good and poor mica undercutting.

is good) held over the core, as shown in figure 6-27, rotate the armature slowly through a complete revolution. If a short is present, the steel strip will become magnetized and vibrate. To find out whether the armature coils of the commutator are short circuited, clean between the commutator segments and repeat the test. Should the thin metal strip still vibrate, the armature is short circuited internally and must be replaced.

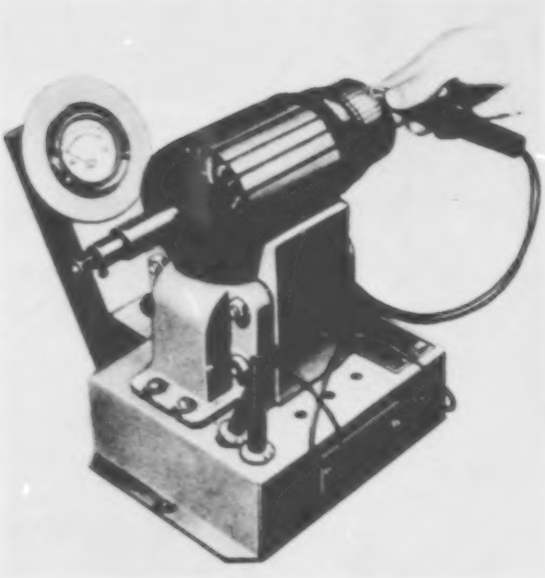
Not all armatures can be tested for short circuits by the method just described. These armatures can be identified by excessive vibration of the saw blade all around the armature during the test. With these armatures, test for short circuits by using the milliampere contacts on an a-c milliammeter as shown in figure 6-28. In doing so, keep the armature stationary in the V-block and move the contacts around the commutator until the highest reading is obtained. Then turn the armature to bring each pair of segments under the contacts and read the milliammeter at the same time. The readings should be nearly the same for each pair of adjacent bars. If a coil is short circuited, the milliammeter reading will drop to almost zero.

Test the armature for grounds by using the test light circuit which is a part of most modern



2.90

Figure 6-27.—Using an armature growler.

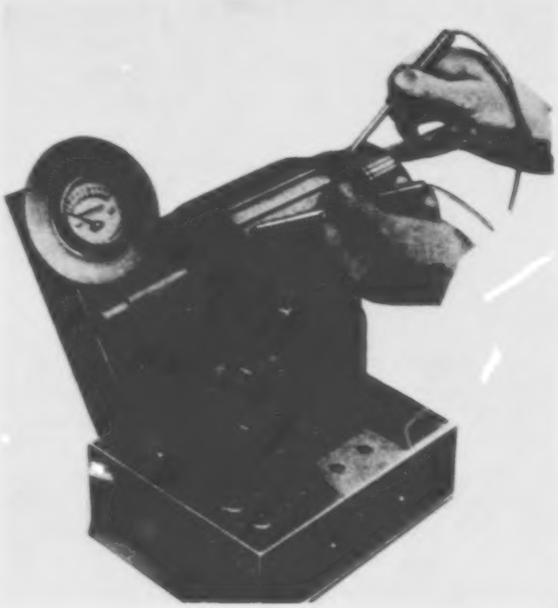


2.91

Figure 6-28.–Testing an armature for short circuits with an a-c milliammeter.

factory-built growlers. (See fig. 6-29.) Place the armature on the V-block and touch one of the test probes to the armature core iron. Touch the other probe to each commutator segment in turn. If the armature is grounded, the bulb in the base of the growler will light. In contacting armature surfaces with the test probes, do not touch bearing or commutator brush surfaces. The arc would burn or pit the smooth finish. Replace the armature if it is grounded.

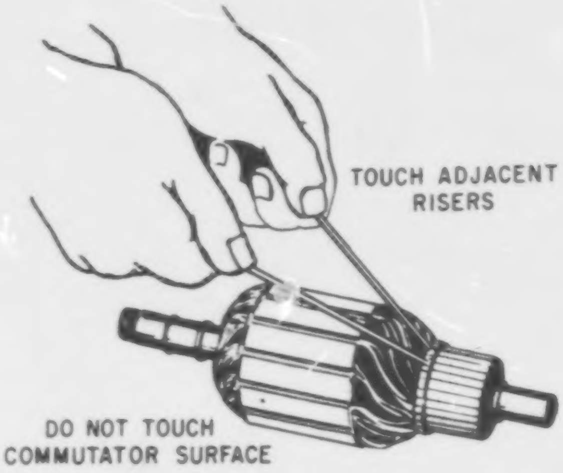
In testing individual armature coils for open circuits, use the test probes as shown in figure 6-30. Place them on the riser part of adjacent commutator bars, not on the brush surfaces. If the test lamp does not light, there is a break somewhere in the coil. Repeat this test on every pair of adjacent bars. Do this by walking the probes from bar to bar. Should you find an open coil, the fault may be at the commutator connectors where it is possible to make repairs with a little solder. If a coil is open circuited internally, the armature should be discarded.



2.92

Figure 6-29.–Testing an armature for grounds.

CHECK BEFORE GENERATOR REASSEMBLY.–Before reassembling the generator, inspect the bearings and bushings. If they are worn considerably, replace them or service them according to the manufactuer's



2.93

Figure 6-30.–Testing armature coils for open circuit.

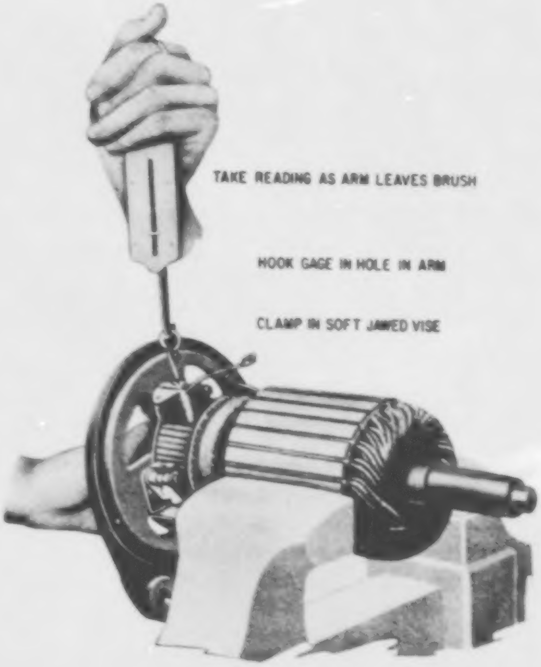
instructions. Clean the bearings by revolving them in cleaning fluid until all grease and dirt are removed. Remove the cleaner with compressed air. However, do not spin the bearings with the air. The high turning speed may damage them, and if blown from your hand, the spinning bearing may injure persons working near you. After cleaning the bearings, repack them with grease recommended by the manufacturer, not ordinary cup grease or chassis lubricant.

Replace any defective insulator, screw, washer, wire lead, stud, or similar small part. While inspecting the field coils or armature before testing them, rewrap or apply insulating shellac to chafed or bare wires. If a coil must be rewrapped, see that the finished job does not extend beyond its original position so that the rotating armature can strike it.

GENERATOR ASSEMBLY.–Having taken the generator apart, you should have little trouble in assembling it. Replace all worn or broken parts, install new brushes, and assemble the generator end frames so that they line up with the field frame assembly. Seat the brushes and check the generator brush spring tension.

Brush spring tension is measured with a scale and hook, as shown in figure 6-31. This tension will vary between 15 and 60 ounces, depending on the generator. Consult the manufacturer's specifications for the proper brush spring tension to use. If the tested spring or springs do not meet specifications, they must be replaced. The tension of a brush spring cannot be satisfactorily adjusted.

POLARIZING THE GENERATOR.–When a generator is installed, tested or repaired, it should be polarized to make sure it has the correct polarity with respect to the battery in the circuit. If the generator is operated with reverse polarity, it may be damaged and, in addition, the regulator contacts may be burned. The method of polarizing a generator will depend on whether the generator field is grounded through the regulator ("A" circuit) or is internally grounded ("B" circuit).



2.94
Figure 6-31.—Measuring brush spring tension.

On "A" circuit generators, with the leads connected, momentarily connect a jumper wire between the "Gen" and "Bat" terminals of the regulator before starting the engine. This permits a momentary surge of current to pass through the generator to polarize it correctly.

For "B" circuit generators, disconnect the lead from the field terminal of the regulator and momentarily touch that lead to the regulator battery terminal.

On vehicles equipped with a double-contact voltage regulator, remove the field lead from the regulator and ground. Then, momentarily place a jumper lead from the battery to the generator armature terminal.

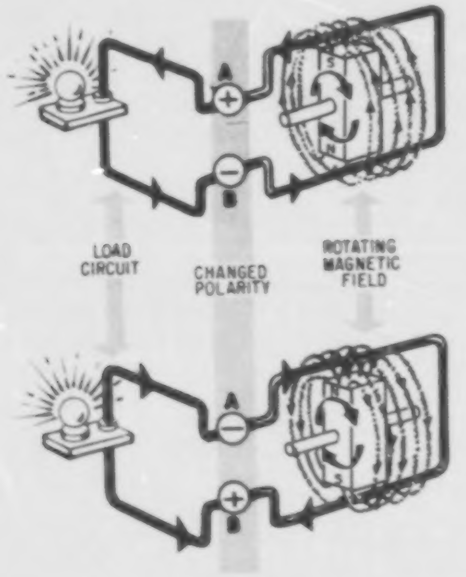
ALTERNATOR

The high current needed to operate comfort and convenience items installed on vehicles and equipment resulted in the d-c generator being replaced, in most applications, with a more efficient generating unit called the ALTERNATOR. Basically, the need called for high current output at low speed, combined with reduced size and weight.

In operation the alternator is somewhat different than the d-c generator. An alternator has a rotating magnet (rotor) which causes the magnetic lines of force to rotate with it. These lines of force are cut by the stationary (stator) windings in the alternator frame as the rotor turns. This induces alternating current and voltage as illustrated in figure 6-32. The current then flows to a diode assembly which allows only direct current to pass.

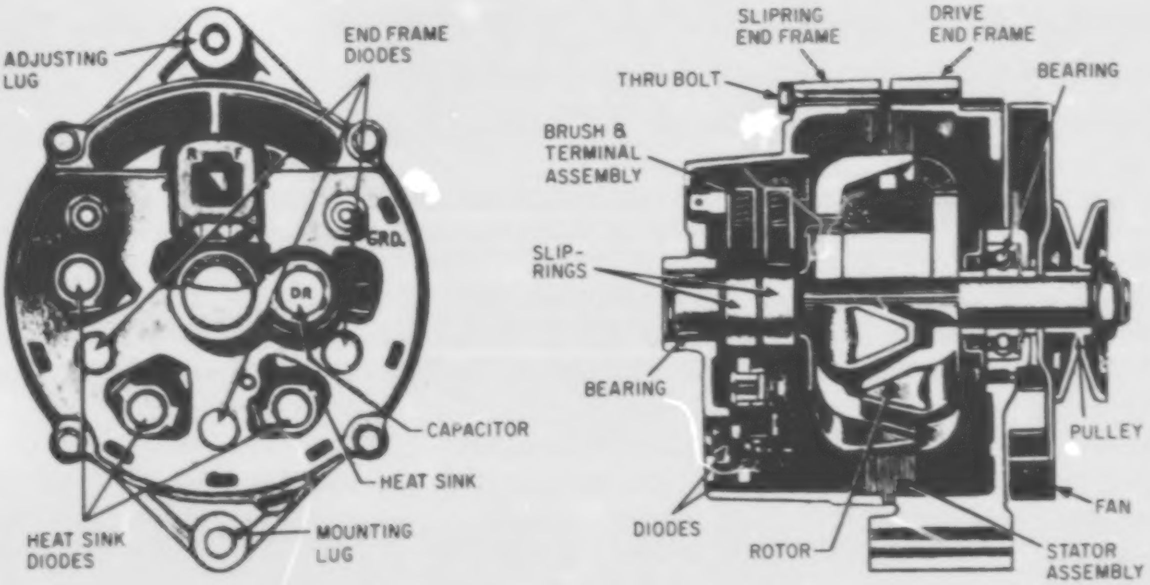
The major components of the alternator (fig. 6-33) are a rotor, a stator, and a diode assembly, all of which are assembled in a unit similar to the d-c generator.

The ROTOR (fig. 6-33) consists of a wire wound into a coil placed over an iron core. Two pole pieces are placed over the coil. Sliprings are added to one end of the shaft and the ends of


A
B
S
N
LOAD CIRCUIT
CHANGED POLARITY
ROTATING MAGNETIC FIELD
A
B
N
S

81.526

Figure 6-32.—Simple alternator illustrating reversing magnetic field and resulting current flow.


ADJUSTING LUG
END FRAME DIODES
R
F
GRD.
DR
CAPACITOR
HEAT SINK
HEAT SINK DIODES
MOUNTING LUG
SLIPRING END FRAME
DRIVE END FRAME
THRU BOLT
BEARING
BRUSH & TERMINAL ASSEMBLY
SLIP-RINGS
BEARING
PULLEY
FAN
DIODES
ROTOR
STATOR ASSEMBLY

224.42

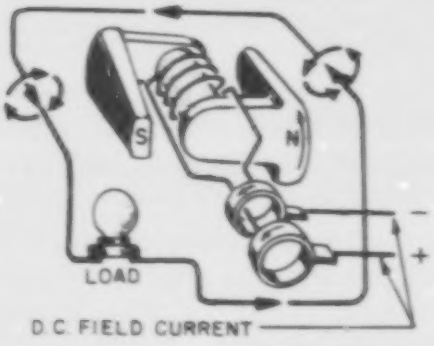
Figure 6-33.—Typical alternator—cross sectional view.

the wire coil are attached to the rings. Brushes, mounted in the end frame of the alternator, are held in contact with the rings by small springs providing a path for the external current required to create the magnetic field of the alternator.

By introducing electric current at one brush, the current will flow via the slipring through the rotor coil and to ground through the other slipring and brush. This current flow creates the magnetic field in the alternator, causing the pole pieces to become north and south poles of the magnet as illustrated in figure 6-34.

The **STATOR** (fig. 6-33), which is part of the alternator frame when assembled, consists of three windings fitted into slots in a laminated frame. One end of these windings is connected in the stator assembly and the other is connected to a pair of diodes, one positive and one negative.

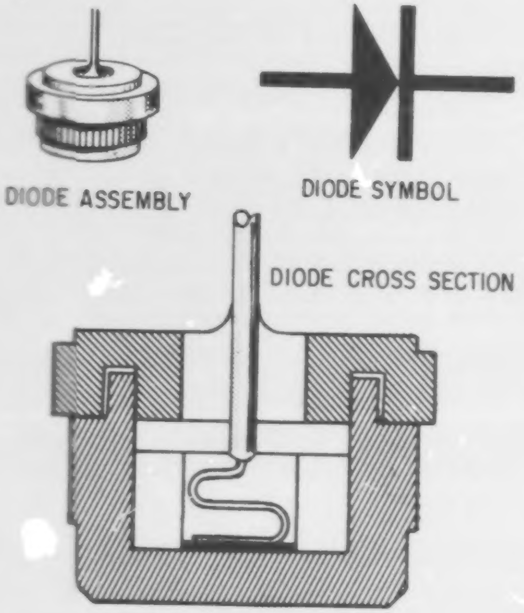
The **DIODE ASSEMBLY** consists of six diodes (fig. 6-33), one pair for each stator winding. The diodes function in pairs. The current flowing from the winding is allowed to pass through the insulated diode. As the current reverses direction, it flows to ground through the grounded diode. The insulated and grounded diodes prevent the reversal of the current from the rest of the charging system. By this switching action, and the number of current pulses created by motion between the windings of the stator and rotor, a fairly even flow of current is supplied to the battery terminal of the alternator. A cross sectional view of a typical diode is illustrated in figure 6-35. Note that the illustration also shows the diode symbol used in wiring diagrams. The arrow in this symbol indicates the only direction that current will flow. The diode is sealed to keep out moisture.



81.527
Figure 6-34.—Alternator field current flow.

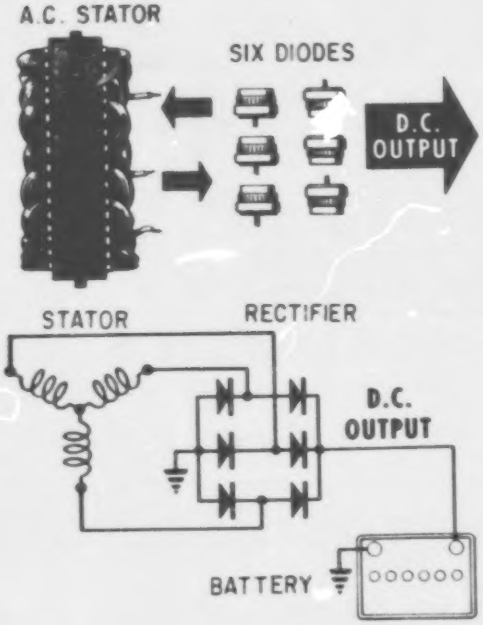
Three negative and three positive diodes are mounted in the end frame of the alternator. The polarity of the electrical system determines which set of diodes are gounded. The remaining set is mounted in an insulated heat sink that is connected to the battery terminal of the alternator.

When the alternator is producing current, the insulated diodes pass only the outflowing current to the battery. The diodes provide a block preventing reverse current flow from the alternator. Figure 6-36 illustrates the flow of current from the stator to the battery.



224.43
Figure 6-35.—Typical diode.

182



224.44
Figure 6-36.–Current flow from the stator to the battery.

Alternators are made in various designs. Some have brushes that can be replaced without removal of the alternator while others do not have brushes. The only thing common to all alternators is their use of a controlling device (regulator) that is matched for use with a specific type alternator. Regulators are not interchangeable.

Alternator Output Control

Output controls for alternators are made and installed in many ways. The magnetic relay type of regulator, which is similar to the d-c generator regulator, came first. Now, most of the regulators are transistorized. They are located inside the alternator case or mounted nearby. With few exceptions, these regulators must be replaced when faulty, as there is no economical way to repair them.

Alternator Maintenance

Alternator testing and service call for special precautions since the alternator output terminal is connected to the battery at all times.

Use care to avoid reverse polarity when performing battery service of any kind. A surge of current in the opposite direction could burn out the alternator diodes.

Do not purposely or accidentally "short" or "ground" the system when disconnecting wires or connecting test leads to terminals of the alternator or regulator. For example, grounding of the field terminal at either alternator or regulator will damage the regulator. Grounding of the alternator output terminal will damage the alternator and possibly other portions of the charging system.

Never operate an alternator on an open circuit. With no battery or electrical load in the circuit, alternators are capable of building high voltage (50 to over 110 volts) which may damage diodes and endanger anyone who touches the alternator output terminal.

Alternator maintenance is minimized by the use of prelubricated bearings and long brushes. If a problem exists in the charging circuit, check for a complete field circuit by placing a large screwdriver on the alternator rear bearing surface. If the field circuit is complete, there will be a strong magnetic pull on the blade of the screwdriver which indicates that the field is energized. If there is no field current, the alternator will not charge becuase it is excited by battery voltage and current.

Should you suspect troubles within the charging system after checking the wiring connections and battery, connect a voltmeter across the battery terminals. If the voltage reading, with the engine speed increased, is within recommended levels, the charging system is functioning properly. Should the alternator tests fail, the alternator should be removed for repairs or replacement. Don't forget, you must ALWAYS disconnect the cables from the battery first.

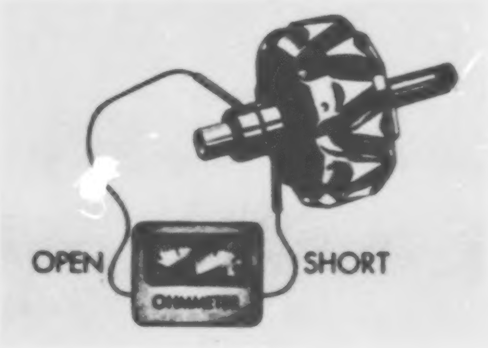
Alternator Disassembly and Testing

To disassemble the alternator, mark the matching portions of the housing to assist in the reassembly after repairs have been made. The brushes need to be removed from some alternators before separating the housing. Check your maintenance manual before disassembly.

Remove the through bolts and separate the housing by lightly tapping the front case, or by gently prying between the front case and stator.

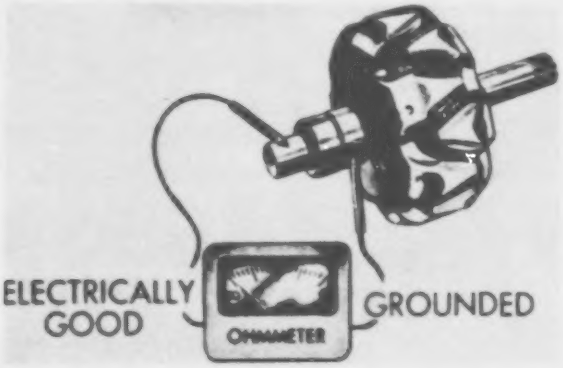
ROTOR TESTING.—The rotor should be tested for grounds, shorts, and opens. To check for grounds, connect a test lamp or ohmmeter from either slipring to the rotor shaft (fig. 6-37). A low ohmmeter reading or lighting of the test lamp indicates that the rotor winding is grounded. To check the rotor winding for opens and shorts, connect an ohmmeter to both sliprings as shown in figure 6-38. An ohmmeter reading below the specified resistance value indicates a short, whereas a reading above the specified value indicates an open. If a test lamp does not light when connected to both sliprings, the winding is open.

STATOR TESTING.—The stator winding can be checked for opens after it has been disconnected from the end frame. If the ohmmeter reading is low or the test lamp lights when connected between each pair of stator leads (fig. 6-39), the stator winding is electrically good. A high ohmmeter reading or failure of the test lamp to light when connected from any one of the leads to the stator frame (fig. 6-40) indicates the winding is not grounded. It is not practical to check the stator for shorts due to the very low resistance of the winding.

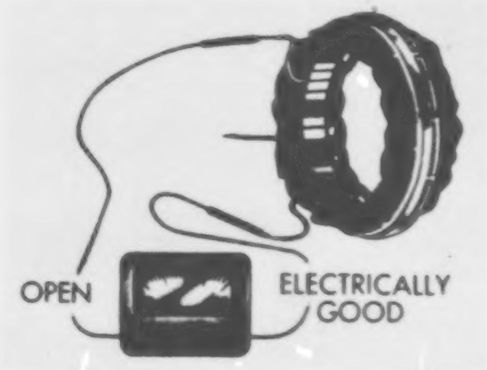


2.311
Figure 6-38.—Testing rotor for opens and shorts.

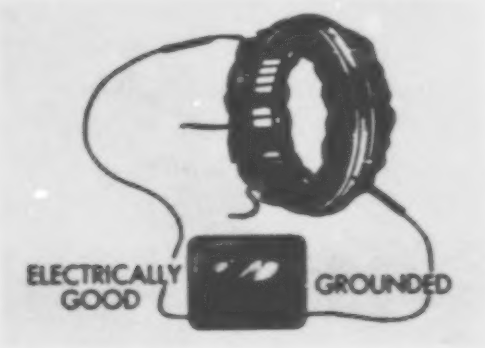
DIODE TESTING.—With the stator windings disconnected, each diode may be tested with an ohmmeter by connecting one test lead to the diode lead, and the other ohmmeter lead to the



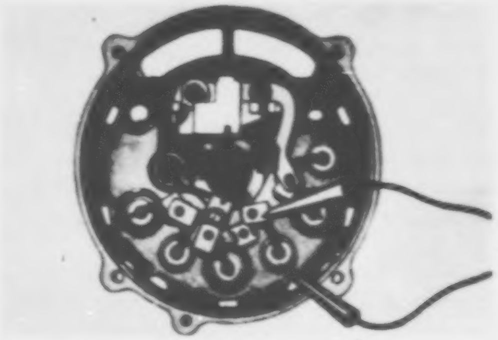
2.310
Figure 6-37.—Testing rotor for grounds.



2.312
Figure 6-39.—Testing stator for opens.

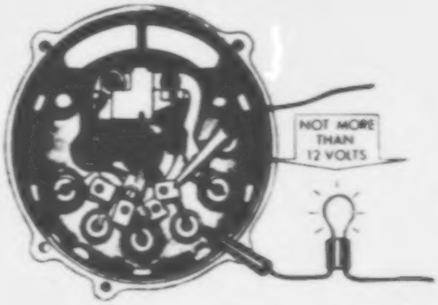


2.313
Figure 6-40.–Testing stator for grounds.



2.314
Figure 6-41.–Testing silicon-diodes with ohmmeter.

diode case, as shown in figure 6-41. Note the reading. Then reverse the ohmmeter leads to the diode and again note the reading. If both readings are very low or very high, the diode is defective. A good diode will give one low and



2.315
Figure 6-42.–Testing silicon-diodes with a test lamp.

one high reading. An alternate method of testing each diode is to use a test lamp with a battery of not more than 12 volts. Connect one of the test leads to the diode lead, and the other test lead to the diode case, as shown in figure 6-42. Then reverse the lead connections. If the lamp lights in both checks, the diode is defective. Or, if the lamp fails to light in either direction, the diode is defective. When checking a good diode, the lamp will light in only one of the two checks.

After completing the required tests and making any necessary repairs or replacement of parts, reassemble the alternator and install on the equipment. After installation, start the equipment and check to insure that the charging system is functioning properly. NEVER ATTEMPT TO POLARIZE AN ALTERNATOR. It doesn't have to be polarized. Attempts to do so serve no purpose and may damage the diodes, wiring, or other charging circuit components.

CHAPTER 7

AUTOMOTIVE ELECTRICITY: PART II

Chapter 6 points out that some electrical systems in Navy equipment contain as many as five circuits; namely, charging, starting, ignition, lighting, and accessories. Of these, the charging circuit was covered in chapter 6; the remaining circuits will be discussed in this chapter. Careful study of the material here and in the preceding chapter will aid you in understanding how these circuits work and in making various adjustments and repairs needed to keep electrical systems in Navy equipment in peak operating condition.

STARTING CIRCUITS

Very little of your equipment will be started by the old fashioned "strong-arm" cranking method; most of it is cranked by an ELECTRIC STARTER–one of the major units of the starting circuit. Starting the engine requires the most current or power draw from the battery, especially on a cold morning when the oil is thick and you can barely "turn it over."

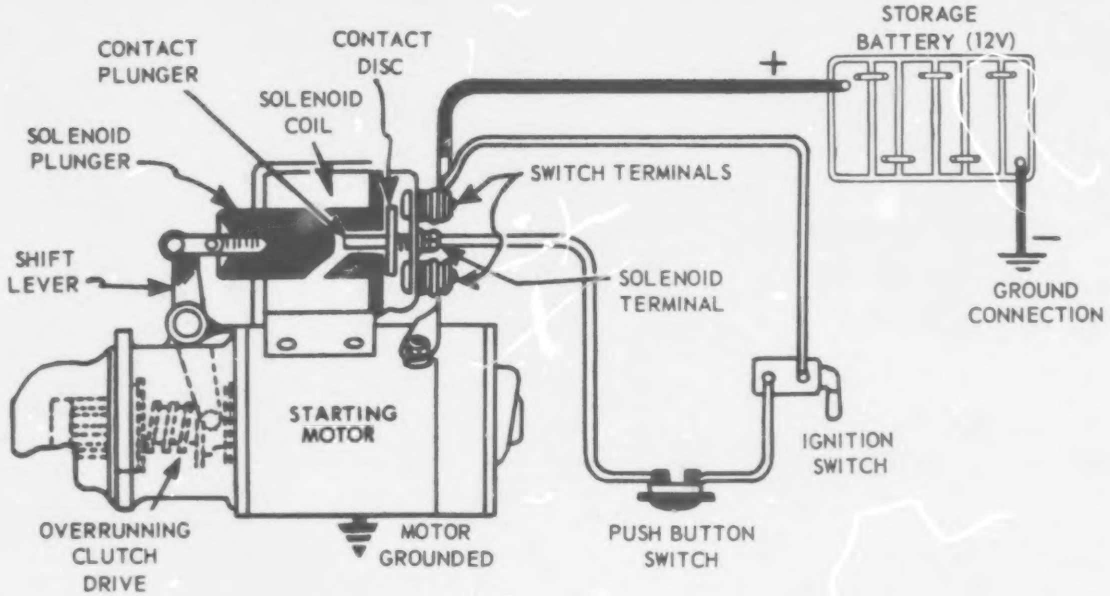
The principal units of a starting circuit include an electric motor, a storage battery, a switch mechanism for starting and stopping the motor, and the essential wiring. In most, if not all equipment, you will probably find a special device which automatically disconnects the starting motor from the engine as soon as the switch is released and the engine begins running under its own power. Almost all self-propelled equipment makes use of more complicated systems, as shown in figure 7-1. Instead of pushing on a directly connected heavy-duty cranking switch, the driver just presses a button on the instrument panel or turns the ignition key to the extreme right or left to start the engine. Pressing the button or turning the ignition switch completes the circuit to the electromagnetic device (solenoid) attached to the cranking motor, as shown in figure 7-1. This device automatically shifts a small gear (pinion) into mesh with the flywheel ring gear and then connects the battery with the starter motor to crank the engine. After the engine starts and the switch is released, the shift lever springs back to disengage the pinion and disconnect the battery from the starting motor. In this system, the ignition switch is connected in the control circuit so that the starter will not operate until the ignition switch is closed.

There are many arrangements of units in starting systems. The battery may be installed under the engine hood, on a running board, or in any convenient place on the vehicle where it will not tilt or be damaged. The starting switch may be located on the starter, the floor of the cab, or the instrument panel. The starter, whether inboard or outboard drive, must be bolted to the flywheel housing. An inboard drive starter is designed so that the pinion moves toward the motor to mesh with the flywheel ring gear teeth, as illustrated in figure 7-2. All inboard drive starter pinions engage as a result of centrifugal force.

Starters in which the pinion moves away from the motor to engage are called outboard drive starters.

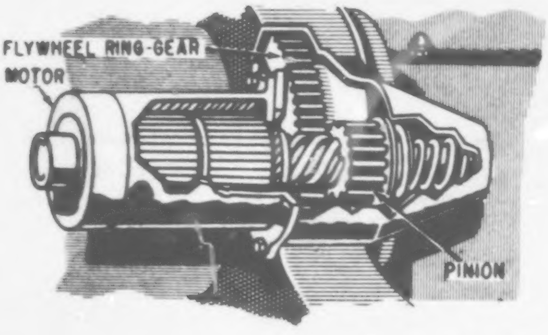
STARTING MOTOR

A starting motor changes electrical energy into mechanical energy. The main difference


CONTACT PLUNGER
CONTACT DISC
SOLENOID COIL
SOLENOID PLUNGER
SHIFT LEVER
STORAGE BATTERY (12V)
+
−
SWITCH TERMINALS
SOLENOID TERMINAL
GROUND CONNECTION
STARTING MOTOR
IGNITION SWITCH
OVERRUNNING CLUTCH DRIVE
MOTOR GROUNDED
PUSH BUTTON SWITCH

81.131

Figure 7-1.—Remote controlled solenoid-operated starting circuit with overrunning clutch drive.


FLYWHEEL RING-GEAR
MOTOR
PINION

81.132

Figure 7-2.—Starting motor with inboard-type Bendix drive.

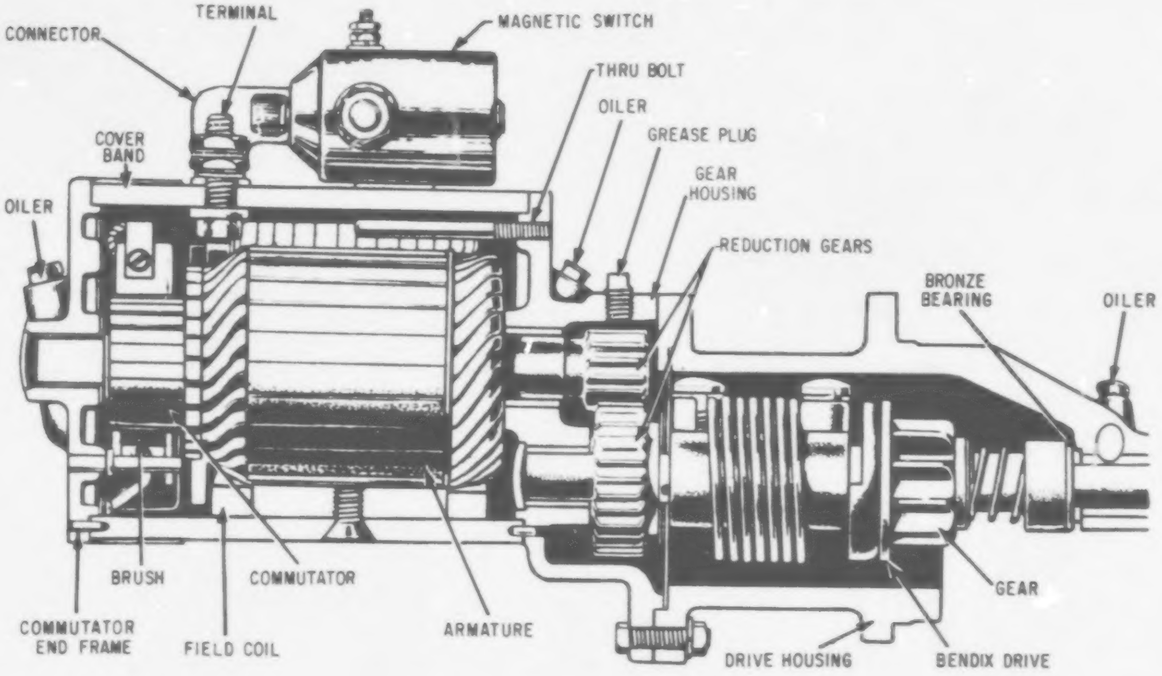
between an electric starting motor and an electric generator is that in a generator, rotation of the armature in a magnetic field produces voltage. In a motor, a current is sent through the armature and the field; the attraction and repulsion between the magnetic poles of the field and armature coil alternately push and pull the armature around. This rotation (mechanical energy), when properly hooked to the flywheel of an engine, will cause the engine's crankshaft to turn.

Starting Motor Construction

Figure 7-3 is a sectional view of a typical heavy-duty starting motor. This particular motor employs a magnetic switch to control the motor, a reduction gear, and a Bendix drive. These units will be discussed later in this chapter.

Except for the drive end and control mechanism, the general construction characteristics of the starting motor are similar to the d-c generator.

The connections and arrangements of the armature coils are such that current is flowing in all the coils at the same time. This allows each coil to add its turning effort to the others, so they all work together to spin the motor armature.


CONNECTOR
TERMINAL
MAGNETIC SWITCH
THRU BOLT
OILER
GREASE PLUG
GEAR HOUSING
COVER BAND
OILER
REDUCTION GEARS
BRONZE BEARING
OILER
BRUSH
COMMUTATOR
GEAR
COMMUTATOR END FRAME
FIELD COIL
ARMATURE
DRIVE HOUSING
BENDIX DRIVE

81.133

Figure 7-3.—Sectional view of a heavy-duty starting motor.

The field windings are used to increase the strength of the magnetic field and thereby increase the power of the motor. The field windings are connected so that the current flows through both the field windings and the armature windings at the same time to produce motoring action. A heavy conductor is used in both the fields and the armature so that the resistance of the motor is very low. This permits an extremely large current to flow, so that the motor develops high torque.

Types Of Starting Motors

Two types of starting motors are found on equipment you will encounter. The predominant one of the two is referred to as direct drive while the other is known as a double reduction starter. All starters require the use of gear reduction that will provide the mechanical advantage needed to turn the engine's flywheel and crankshaft.

DIRECT DRIVE STARTERS make use of a pinion gear on the starting motor's armature shaft. This gear meshes with teeth on the engine flywheel. There are from 10 to 16 teeth on the flywheel for every tooth on the starting motor pinion. Therefore, the starting motor armature revolves 10 to 16 times for every revolution of the engine flywheel. In operation, the starting motor armature revolves at a rate of 2000 to 3000 revolutions per minute, thus turning the engine crankshaft at speeds up to 200 revolutions per minute.

DOUBLE REDUCTION STARTERS make use of a gear reduction, in addition to the reduction between the drive pinion and the flywheel. The gear reduction drive head is used in heavy-duty equipment.

Figure 7-3 illustrates a typical gear reduction starting motor. The gear on the armature shaft does not mesh directly with the teeth on the flywheel but with an intermediate gear which drives the flywheel driving pinion. This drive permits the use of a small starting motor running at high speeds. This provides additional breakaway, or starting torque, and greater cranking power. On some starting motors with a gear reduction drive head, the cranking motor armature may turn, during cranking, as many as 40 times for every revolution of the engine flywheel.

When the engine begins to operate it may be speeded up to 3000 to 4000 revolutions per minute. If the starting motor did not de-mesh from the flywheel teeth, the starting motor armature would be spun at speeds up to 60,000 revolutions per minute. These high speeds would throw the windings from the slots in the armature and the segments from the commutator. To prevent this, various methods of meshing and de-meshing the starting motor pinion with the flywheel have been devised.

Starter Engaging Mechanisms

Engaging mechanisms found on starters you will encounter are of three designs: Bendix, overrunning clutch, and Dyer drive. The Bendix drive is normally used on engines of relatively low cylinder displacement and horsepower. The overrunning clutch and Dyer drive are used on heavy-duty engines.

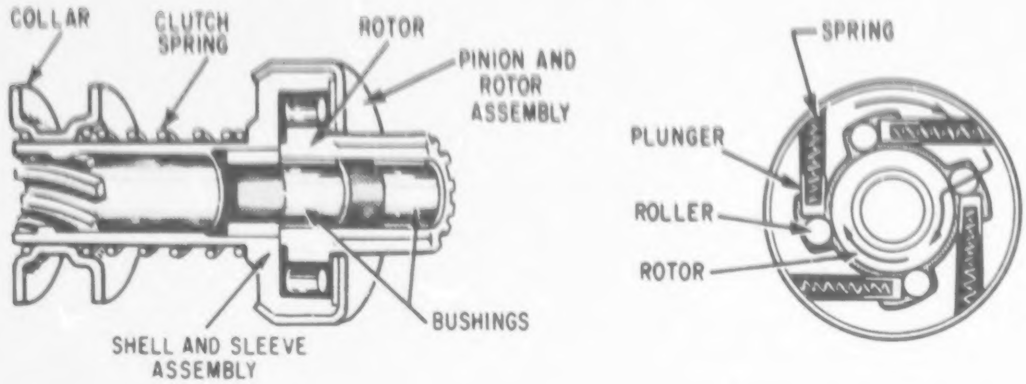
The BENDIX DRIVE (fig. 7-3) is one device that accomplishes meshing and de-meshing of the drive pinion with the flywheel. It relies upon the principle of inertia to cause its pinion to mesh.

When the starting motor is not operating, the pinion is out of mesh and entirely away from the flywheel gear. When the starting motor switch is engaged and the total battery voltage is applied to the starting motor, the armature immediately starts to rotate at high speed.

The pinion, being weighted on one side and having internal screw threads, does not rotate immediately with the shaft but, because of inertia, runs forward on the revolving threaded sleeve until it meets or engages with the flywheel gear. If the teeth of the pinion and the flywheel meet instead of engaging, the drive spring allows the pinion to revolve and forces it into mesh with the flywheel. When the pinion gear is fully engaged with the flywheel gear, the pinion is then driven by the starting motor through the compressed drive spring and cranks the engine. The drive spring acts as a cushion while the engine is being cranked against compression. When the engine fires and runs on its own power, the flywheel drives the pinion at a higher speed than does the starting motor, causing the pinion to turn in the opposite direction on the threaded sleeve and automatically disengage from the flywheel. This prevents the engine from driving the starting motor. Several other types of inertia or Bendix-type drives are also in use. Although they may differ considerably in looks and construction, their method of operation is similar in many respects to the Bendix drive just discussed.

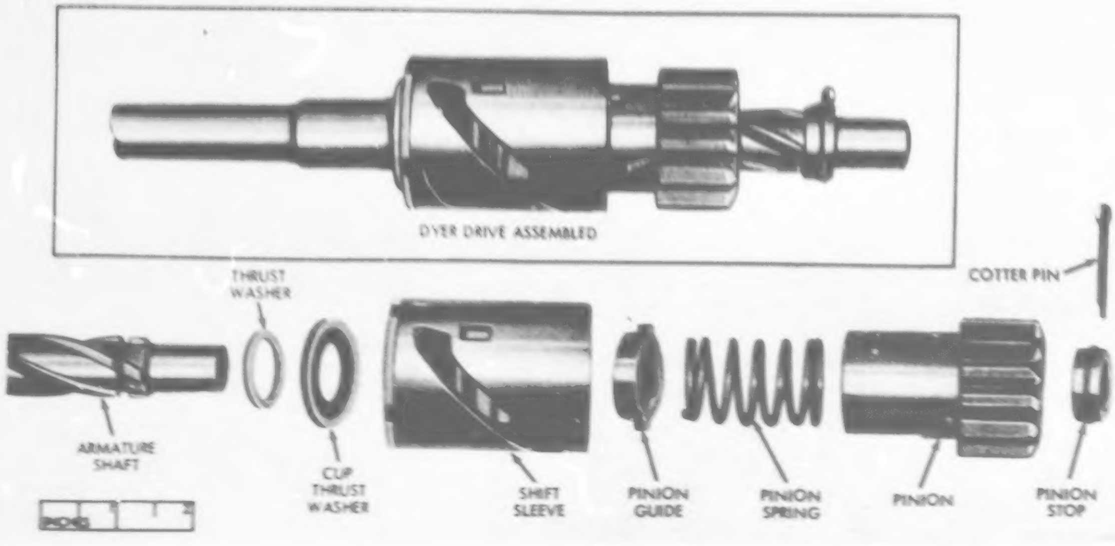
The OVERRUNNING CLUTCH provides positive meshing and de-meshing of the starting motor pinion gear and engine flywheel gear. The shell and sleeve assembly of the clutch (fig. 7-4) is driven by the starting motor armature shaft. The rotor assembly is connected to the pinion gear, which meshes with the engine flywheel gear. Spring-loaded steel rollers are located in tapered notches between the shell and the rotor. The springs and plungers hold the rollers in position in the tapered notches. When the armature shaft turns, the rollers are jammed between the notched surfaces, forcing the inner and outer members of the assembly to rotate as a unit and crank the engine. After the engine is started, the flywheel rotates faster than the pinion gear, thus tending to work the rollers back against the plungers (fig. 7-4), and thereby causing an overrunning action. This action prevents excessive speed of the motor. When the starting motor is released, the collar and spring assembly pulls the pinion out of mesh with the flywheel gear.

The DYER DRIVE (fig. 7-5) is another type of starting motor drive which combines some of the principles of both the Bendix and the overrunning clutch drives. You will find the Dyer drive commonly used on heavy-duty gasoline and diesel engines. It provides complete and positive meshing of the drive pinion and the flywheel teeth before the starting motor is energized.


COLLAR
CLUTCH SPRING
ROTOR
PINION AND ROTOR ASSEMBLY
SHELL AND SLEEVE ASSEMBLY
BUSHINGS
SPRING
PLUNGER
ROLLER
ROTOR

81.134

Figure 7-4.—Typical overrunning clutch construction.


DYER DRIVE ASSEMBLED
THRUST WASHER
COTTER PIN
ARMATURE SHAFT
CUP THRUST WASHER
SHIFT SLEEVE
PINION GUIDE
PINION SPRING
PINION
PINION STOP
INCHES
1
2

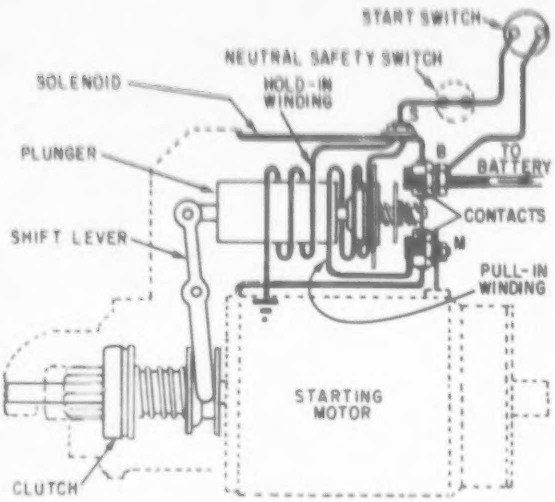
81.136

Figure 7-5.—Dyer drive.

Starting Motor Controls

There are various types of controls used with starting motors. The most common type that you will encounter is the SOLENOID, shown in figure 7-6. This magnetic switch or solenoid is mounted directly on the starter and is actuated by the ignition switch, or by a starter button connected in the circuit between the battery and the starter.

In operation, the solenoid is actuated when the ignition or starter button is depressed. This



81.528

Figure 7-6.–Typical starting circuit with neutral safety switch.

causes current to flow through the solenoid (causing a magnetic attraction of the plunger) to ground.

The movement of the plunger causes the shift lever to engage the pinion with the flywheel ring gear. After the pinion is engaged, further travel of the plunger causes the contacts inside the solenoid to close and directly connect the battery to the starter.

After the engine is started, releasing the starter button or ignition key will stop the flow of current through the solenoid. The plunger spring returns the plunger to its normal rest position, causing the shift lever to move the starter pinion away from the flywheel. This prevents accidental starter pinion engagement while the engine is operating

If cranking continues after the control circuit is broken, it is probably caused by a shorted turn in the solenoid windings or by binding of the plunger within the solenoid. Low voltage from the battery is often the cause of the starter making a clicking noise. When this occurs, the connections in the starting circuit should be examined for cleanliness and tightness.

A RELAY is frequently used in the control circuit to supply current to the solenoid coils. Only a low current control circuit is needed to the instrument panel switch with this application. This relay is used to close the circuit between the battery and the solenoid. Relays of this type are commonly found on 24-volt starting circuits.

Some starting circuits use the relay and no solenoid on the starter. This method of starter control is common to all starters that have no shift mechanism for the starter pinion.

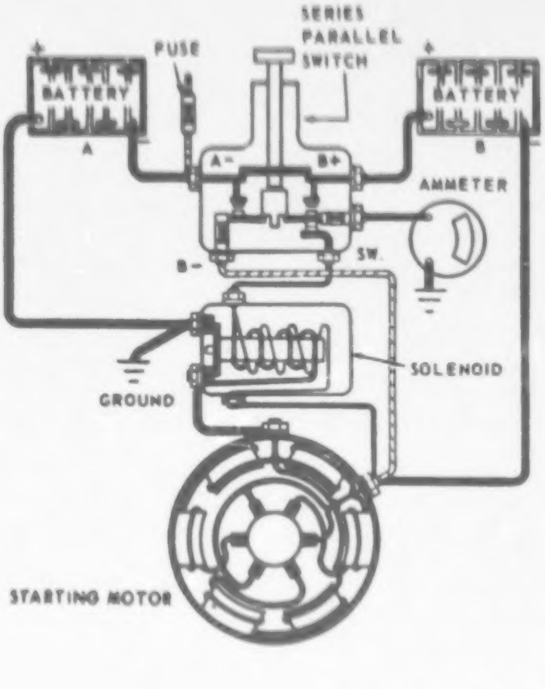
Navy vehicles or equipment with automatic transmissions have an additional item in the starting circuit called a NEUTRAL SAFETY SWITCH. This switch, which is actuated by the transmission shift linkage, prevents accidental starting of the engine while the transmission is in gear. Some of the newer standard shift vehicles have a similar switch that requires the operator to depress the clutch pedal before the starter will operate. For safety reasons, THIS SWITCH SHOULD FUNCTION PROPERLY AT ALL TIMES.

SERIES-PARALLEL STARTING CIRCUIT

Because of the high compression ratios of some diesel engines, a high voltage is often necessary to insure sufficient starting power. A series-parallel switch provides a series connection of the batteries for starting and a parallel connection for normal operation.

For example, two 12-volt batteries connected in series will supply 24 volts; but two 12-volt batteries connected in parallel will supply only 12 volts.

The series-parallel starting switch, when operated, disconnects the batteries from their parallel connection and reconnects them in series to the starting motor. Figure 7-7 shows a series-parallel switch depressed so that the two 12-volt batteries, A and B, are connected in series for starting. The following description will



2.90

Figure 7-7.—Series-parallel switch circuit, showing batteries connected in series for starting.

help you understand its operation so that you may locate troubles, if and when they occur.

The starting motor solenoid circuit is connected to ground at the plus terminal of battery A through a pair of contacts in the series-parallel switch. The other side of the solenoid is connected to the minus terminal of battery B. This imposes 24 volts on the solenoid, so that it operates to mesh the starter drive pinion with the engine flywheel, and closes the circuit from the batteries to the starting motor. Since the two batteries are connected in series through the heavy contact disk and heavy contacts of the series-parallel switch, 24 volts instead of 12 volts are imposed on the starting motor.

After starting, the series-parallel switch pedal is released and the two batteries become connected in parallel to provide 12-volt operation of other electrical accessories. (See fig. 7-8.) Spring tension pulls the heavy series-parallel switch disk away from the heavy contacts and opens the series connections at the A- and B+ terminals of the switch. At the same time, the small contacts within the switch, connected to the B-, the SW (switch), and the ground terminals, move to complete the circuit connecting the batteries in parallel.

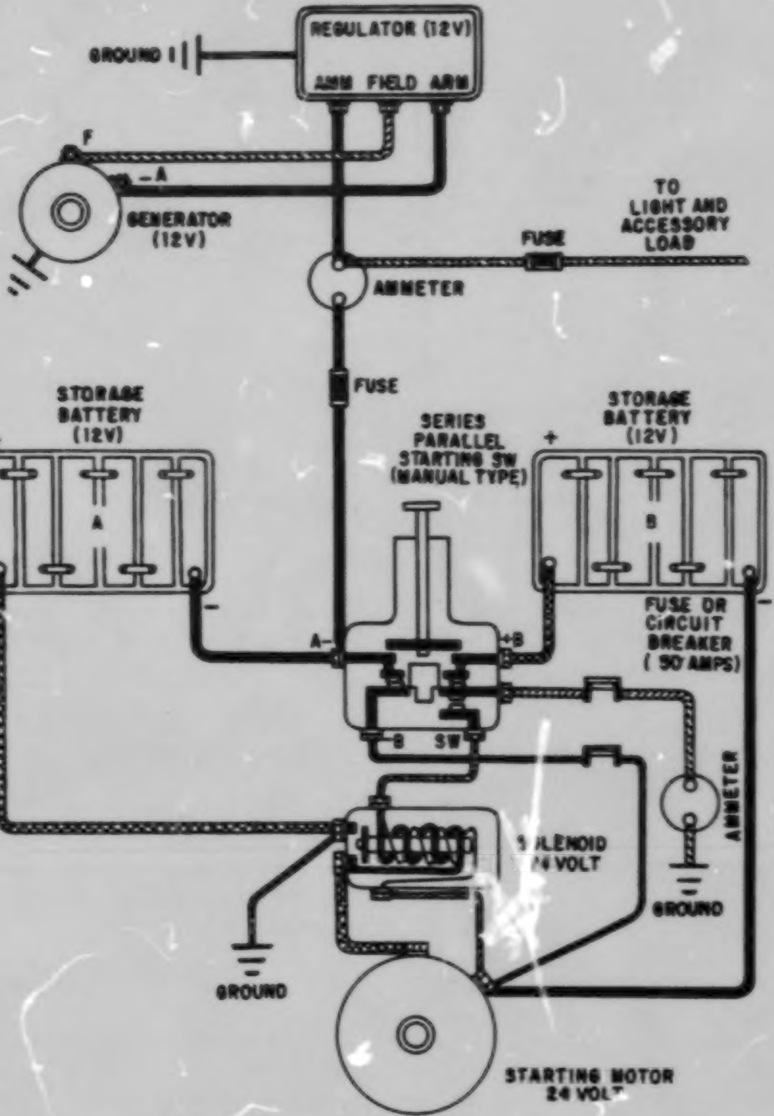
During normal operation, generator charging current enters this two-battery system at the A- terminal of the switch. It divides as it enters; part of the current entering the A battery, the other part going through the contacts in the series-parallel switch, down to the starting motor and from there to the minus terminal of the B battery. The current from the A battery flows directly to ground and then back to the generator. The current from the B battery flows through the series-parallel switch to ground and then back to the generator.

The ammeter in the series-parallel system registers one-half of the current flowing from the generator to the batteries; it registers the half which is entering and charging battery B. This provides a check on the operation of the system. With two batteries connected in parallel, as the electrical load increases, half the current required is withdrawn from each battery.

During the starting interval, the 12-volt supply for lights and other accessories is taken from the A battery only.

CAUTION: In making repairs to vehicles provided with a series-parallel starting circuit, avoid careless grounding of the starting switch terminals. For example, a short circuit caused by a wrench or an oil measuring stick may result in a tremendous surge of current through the series circuit and seriously damage the equipment.

Normally, fuses are incorporated in the parallel circuit of the system to provide protection from some careless action. The fuses may be inside the series-parallel switch terminals, or they may be included in the circuits outside of the switch. In addition to fuses, all exposed terminals are often taped and shellacked so that the terminals cannot be easily grounded.


REGULATOR (12V)
GROUND
ARM
FIELD
ARM
F
A
GENERATOR (12V)
TO LIGHT AND ACCESSORY LOAD
FUSE
AMMETER
FUSE
STORAGE BATTERY (12V)
SERIES PARALLEL STARTING SW (MANUAL TYPE)
STORAGE BATTERY (12V)
+
A
B
+
−
A−
+B
−
FUSE OR CIRCUIT BREAKER (50 AMPS)
B
SW
SOLENOID 24 VOLT
AMMETER
GROUND
GROUND
STARTING MOTOR 24 VOLT

2.100

Figure 7-8.—Series-parallel switch with batteries connected in parallel.

STARTING CIRCUIT MAINTENANCE

The condition of the starting motor should be carefully checked at each PM service. This will permit you to take appropriate action, where needed, so that equipment failures caused by a faulty starter can be reduced, if not eliminated.

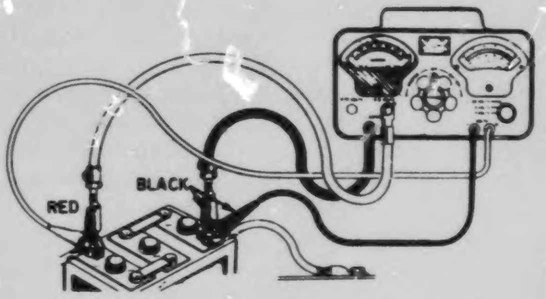
A visual inspection for clean, tight electrical connections and secure mounting at the flywheel housing is about the extent of a maintenance check. Operate the starter and observe the speed of rotation and steadiness of operation. During this check, never operate the starter for more than 30 seconds without allowing it to cool. The starting motor normally runs only for a few seconds each time it is used and carries a great overload when running. To carry such a heavy load, it draws a high current. This current, 100 to 550 amperes (depending on the type of engine it is used on), causes the starter to heat up rapidly. The heat generated will cause the insulation inside the starter to fail, resulting in damage to the starter by internal shorting of the windings.

Replacing the Bendix spring is a common job associated with repairing starters. When the operator reports hearing the cranking motor spinning without turning the engine, you will know the Bendix spring is broken or that the fastening screw bolts have been sheared.

If you are checking the starter and it barely turns the engine or it makes a series of loud clicks, you can be fairly sure there is a problem with the battery. Starters seldom fail unless they are used excessively. Since the starter relies completely on the battery for its proper operation, a battery capacity test should be made before the starter is removed for repair or replacement.

Battery Capacity Test

To make a battery capacity test you must know the ampere-hour rating of the battery. This is generally stamped on the battery case. If it is not, consult the manufacturer's manual. Connect the battery starter tester as shown in figure 7-9. Turn the variable resistor control knob on the tester clockwise until the ammeter reads three times the ampere-hour rating of the battery; for example, 360 amperes for a 120-ampere-hour battery. With the test ammeter reading the specified load for 15 seconds, note the voltmeter reading. Turn the variable resistor control knob to the OFF position and refer to battery test indications and recommendations. If the test indicates that the battery is in satisfactory condition, remove the starter for repair or overhaul.



2.97
Figure 7-9.—Instrument hookup for battery capacity test.

Starter Removal And Replacement

Prior to removing the starter, disconnect the cables and wiring and remove the mounting bolts. Remove the starter carefully in order to prevent dropping it on the floor and damaging the housing or connections.

The similarity of construction between the d-c generator and starting motor allows the same basic procedures to be used for disassembly and repairs. The starter drive, if faulty, in most cases is not repairable and must be replaced as a unit. If the brushes are worn to half their normal length, they should be replaced. Brush spring tension should be tested at the time of reassembly to insure that the brushes are held firmly against the armature when assembled.

When cleaning armature or field windings, do not use a grease-dissolving or high-temperature cleaning solution, as it may damage the insulation.

Test the operation of the drive pinion on the overrunning clutch drive unit. It should turn freely in the overrunning direction, and should not slip in the driving direction. Clean the Bendix drive, on starters so equipped, with a suitable cleaning agent and apply a light coat of engine oil on the spiral sleeve. Do not use grease to lubricate the drive mechanism. This will usually result in failure of the mechanism to function properly.

Before installing the starting motor in the flywheel housing, be sure to bend the tabs on the lock-washer under the Bendix spring-fastening screws against the screw heads to hold the screws securely in place. Also inspect the pinion gear for wear and burred edges. A worn pinion gear is often responsible for a motor being stuck or locked in the engine flywheel.

A locked starting motor can sometimes be freed by cranking the engine with the handcrank. If there is no handcrank, or if the pinion will not release by this method, you can try putting the vehicle in forward gear and pushing it backwards. Loosening the starting motor fastening bolts to release the starting motor is often the best method and the safest.

IGNITION CIRCUITS

Ignition, or burning of the fuel and air mixture within the engine, is accomplished by one of two methods. The gasoline engine relies on an electrical spark at the spark plug while the diesel uses the heat from compression to ignite the fuel. Since compression ignition is inherent with the diesel, only those ignition circuits used with the gasoline engine will be discussed in this chapter.

Conventional ignition circuits are of two types: BATTERY and MAGNETO. Both types perform the same function of providing a high voltage spark, at the right time during the operating cycle, to ignite the mixture in the engine's cylinder. A variation of the battery ignition circuit, called the transistorized ignition, is rapidly replacing the old breaker type ignition. The newer design is an improvement over the breaker type and is virtually maintenance-free for many miles or hours of operation.

THE BATTERY IGNITION SYSTEM

The battery ignition systems you will encounter in Navy equipment are either 12-volt or 24-volt systems. The ignition systems are actually made of two separate circuits which work together to cause the spark at the spark plug. These two circuits consist of the PRIMARY (circuit with reduced battery voltage) and the SECONDARY (circuit with coil voltage).

Primary Circuit

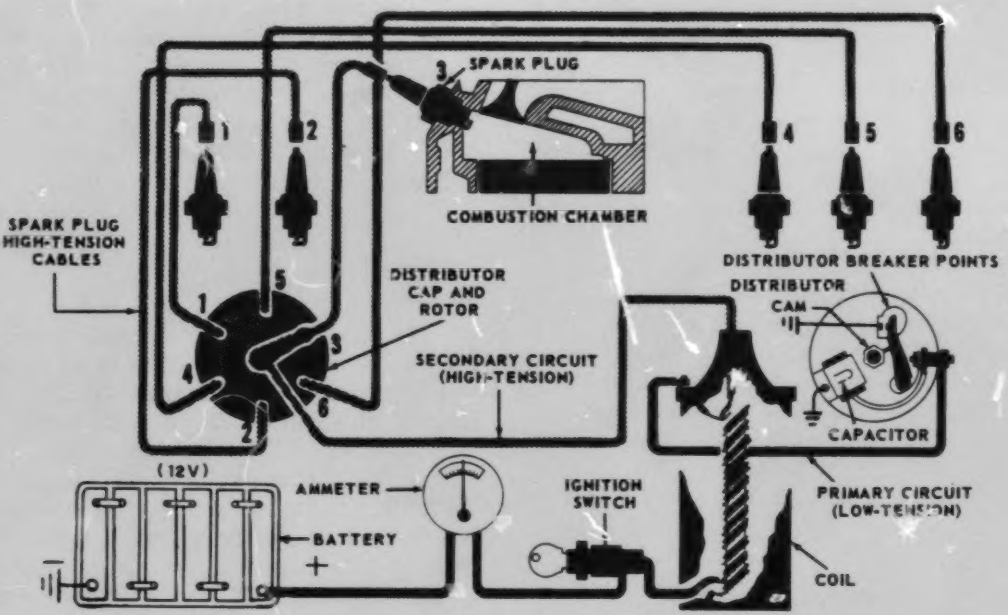
The function of the primary circuit is to provide the voltage and current to create the magnetic field at the ignition coil. In the diagram in figure 7-10, you can trace the two circuits of the battery-ignition system. The low voltage circuit shown as solid black in the illustration contains battery voltage. This circuit is known as the primary circuit. Current flows through this circuit to ground only when the ignition points are closed. Resistance is placed in this circuit to cause increased point life. A resistor, or wiring in which the conductors have resistance, reduces primary voltage to approximately 6 volts during normal operation.

Secondary Circuit

The secondary circuit is the high voltage circuit of the ignition system. This circuit carries the high voltage from the secondary windings of the ignition coil to electrodes in the distributor cap, then through the wiring to the spark plugs.

Ignition Coil

The ignition coil (fig. 7-11) is made of a soft iron core surrounded by two coils of wire. The inner coil, or SECONDARY WINDING, is a fine wire consisting of approximately 22,000 turns. The outer PRIMARY WINDING is made up of only about 200 turns of heavy gage wire, the ends of which are attached to the primary terminals of the coil. The secondary winding is wound in the opposite direction of the primary. Its ends are attached internally to the primary winding and the coil tower (high tension terminal).


SPARK PLUG
3
1
2
4
5
6
COMBUSTION CHAMBER
SPARK PLUG HIGH-TENSION CABLES
DISTRIBUTOR CAP AND ROTOR
5
1
3
4
6
2
SECONDARY CIRCUIT (HIGH-TENSION)
DISTRIBUTOR BREAKER POINTS
DISTRIBUTOR CAM
CAPACITOR
PRIMARY CIRCUIT (LOW-TENSION)
(12V)
AMMETER
BATTERY
−
+
IGNITION SWITCH
COIL

81.138

Figure 7-10.—Schematic wiring circuits of a battery ignition system.

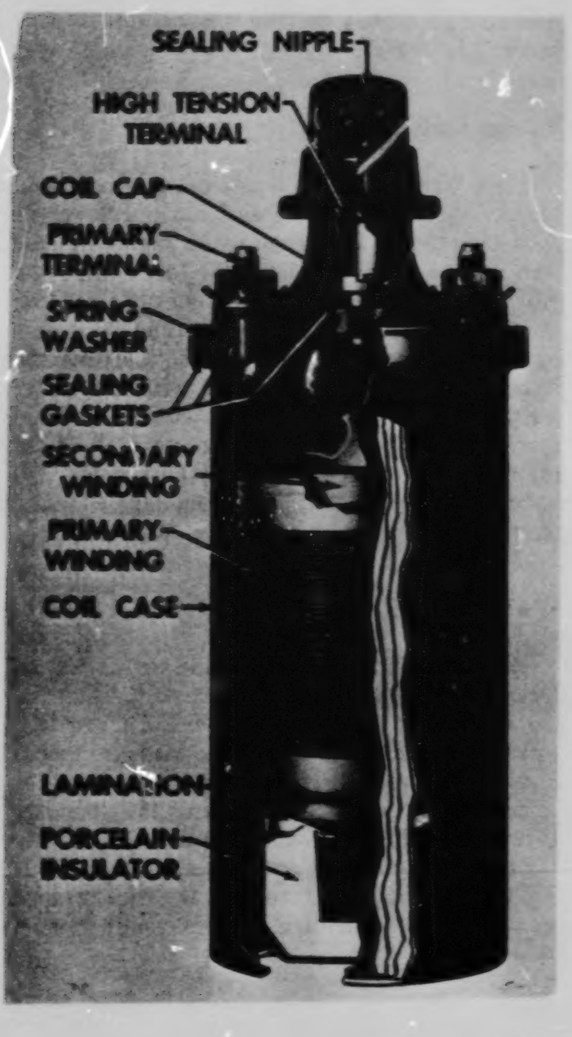
To obtain the high voltage needed in the secondary circuit, the primary circuit is opened (stopping current flow), causing the magnetic field in the ignition coil to collapse. As the magnetic field collapses, a high electrical voltage is induced into the secondary circuit (approximately 1 volt for each turn of wire contained in the secondary windings).

Since both the primary and secondary windings of an induction coil are stationary windings, some means other than movement of the windings must be found to change the magnetic field surrounding the coils. In practice, this effect is CREATED by a switch device in the primary circuit. When the primary circuit is complete, current flows through the primary coil winding, and the magnetic field builds up around it. In building up, the magnetic lines of force link the primary and secondary windings and induce voltage in each winding. In the primary winding, the induced voltage opposes the battery voltage. For this reason, the magnetic field is not built up instantly, but requires a fraction of a second to reach full strength. This is called the saturation period.

Contact Points And Cam

The switch, which consists of contact points and rotating cam, is located in the distributor. The job of this device is to cause intermittent current flow in the primary circuit, thus causing the magnetic field in the coil to build up and then collapse when it reaches maximum strength. The collapse induces a surge of high voltage in the secondary winding, and causes a brief but strong flow of current in the secondary circuit. The flow of current in the secondary circuit makes a spark jump across the gap of the particular spark plug, which is connected into the secondary circuit by means of the distributor.

The collapse of the magnetic field also induces a moderately high-voltage surge in the primary coil winding, because this coil is also



77.156

Figure 7-11.—Sectional view of an ignition coil.

surrounded by the collapsing magnetic lines of force.

Condenser

If nothing were done about the surge of induced current through the primary circuit, ARCING would occur across the distributor points. To reduce arcing, which would quickly burn and damage the contact points, the CONDENSER (capacitor) is wired in parallel with the contact points and grounded through the distributor housing. The condenser takes up the current from the induced primary voltage, allowing the magnetic field to collapse very quickly and induce a high secondary voltage. The result is a good high-voltage spark, which is needed to ignite the fuel-air charge.

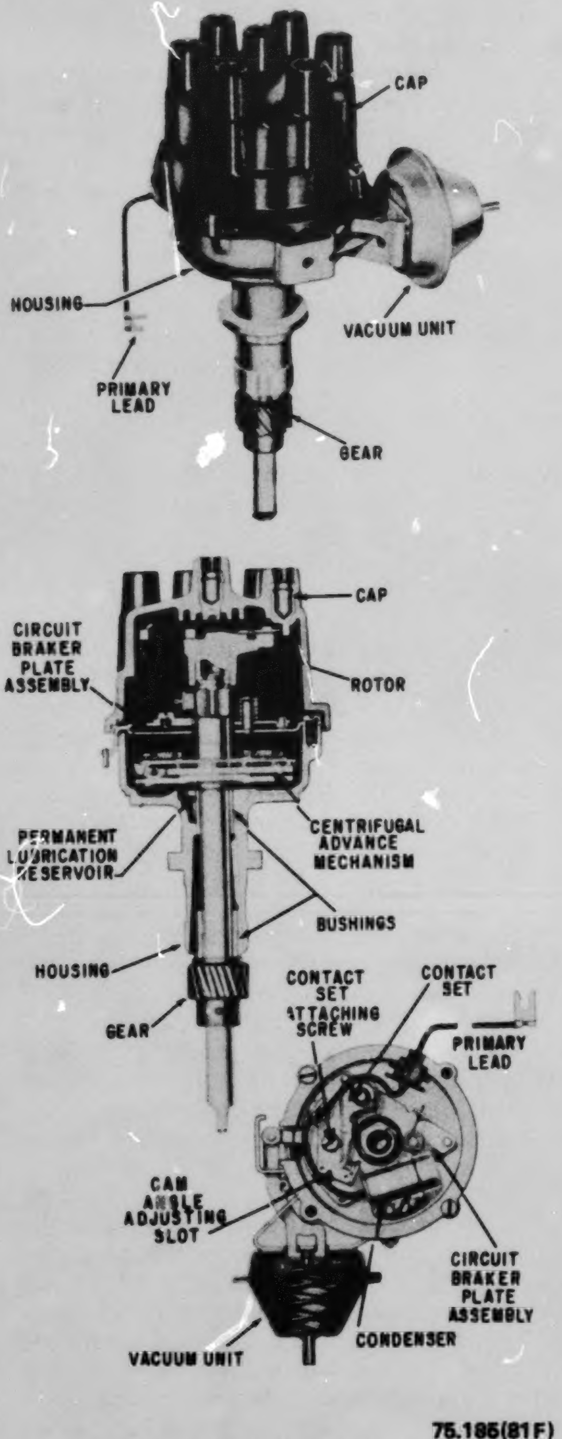
Induced voltages in the primary and secondary coil windings depend on the number of turns of wire in the two windings. The voltage induced in the secondary winding when the field collapses may be as high as 20,000 volts. Actually, the spark usually jumps at a lower voltage—approximately 10,000 volts; the secondary voltage probably never goes as high as 20,000 volts, unless there is excessive resistance in the secondary circuit.

Distributor

Figure 7-12 is a sectional and top view of the distributor unit. The distributor's main functions are as follows: (1) to open and close the primary circuit to produce the magnetic buildup and collapse in the ignition coil; (2) to conduct the high voltage surges from the secondary winding at the proper time; and (3) to direct these high voltage surges to the proper spark plugs.

The distributor cap has separate terminals for the high-tension leads to the spark plugs. The cap fits over the distributor housing that contains the condenser and breaker cam. The breaker cam and the rotor rotate at one-half engine speed on a shaft which is driven by the camshaft or oil pump. The rotor conducts the high-voltage surge from the secondary to the separate spark plug leads.

The distributor shaft is so designed that the rotor makes contact with one of the spark plug leads each time the primary circuit is broken and the high voltage surge occurs. Note in figure 7-10 that the spark plugs and cylinders are numbered in a standard manner beginning with number 1 at the front of the engine, working on back to number 6 (6-cylinder engine) at the rear of the engine. The leads from the distributor cap


CAP
HOUSING
VACUUM UNIT
PRIMARY LEAD
GEAR
CAP
CIRCUIT BRAKER PLATE ASSEMBLY
ROTOR
PERMANENT LUBRICATION RESERVOIR
CENTRIFUGAL ADVANCE MECHANISM
BUSHINGS
HOUSING
GEAR
CONTACT SET ATTACHING SCREW
CONTACT SET
PRIMARY LEAD
CAM ANGLE ADJUSTING SLOT
CIRCUIT BRAKER PLATE ASSEMBLY
CONDENSER
VACUUM UNIT

75.185(81F)

Figure 7-12.—Side and top view of a distributor.

are so arranged that the rotor will direct the high-voltage surges to the plugs in the firing order 1-5-3-6-2-4.

Breaker Cam

The breaker cam is a part of, or is attached to, the distributor shaft and has one lobe for each cylinder in a 4-stroke cycle engine. As the cam rotates with the shaft, the lobes cause the movable contact arm to move and open or close the primary circuit. At the same time the points open, a rotor attached to the end of the distributor shaft and in contact with the center distributor cap contact alines with one of the spark plug wire terminals. This provides a path for the high voltage induced in the ignition coil to reach the spark plug in the engine and ignite the fuel/air mixture.

SPARK ADVANCE

For efficient engine operation under all speed and load conditions, it is essential that the spark occur at the correct instant. That instant will vary according to the engine load and speed. For this reason, a mechanism is provided to automatically advance or retard the spark as engine operating conditions require. On gasoline engines that you will encounter, two methods are usually employed to actuate the advance mechanism: centrifugal force and engine vacuum.

Centrifugal Advance

When the engine is idling, the spark generally is timed to occur just before the piston reaches the top of the compression stroke. At higher engine speed, there is less time for the fuel mixture to ignite and expand. For this reason, some means is necessary to advance the time the spark occurs in the cylinder.

This spark advance is accomplished by means of the centrifugal advance mechanism (fig. 7-12). The advance mechanism may be found either above or below the breaker plate assembly.

The centrifugal advance mechanism consists of two weights which tend to move outward against spring tension as the distributor shaft rotates. The faster the rotation of the shaft, the greater the movement of the weights. In older distributors, movement of the weights was transmitted to the breaker cam so that the cam rotated in an advanced position in relation to the distributor shaft. Most advance mechanisms that you will encounter today have a rigidly attached cam on the shaft and the breaker plate is caused to move.

To obtain maximum efficiency during part-throttle operation, a device known as a vacuum unit, is used to provide the required spark advance. This vacuum unit is needed because the speed of the shaft does not cause the spring-loaded weights to move far enough.

Vacuum Advance

A conventional vacuum unit (fig. 7-12) utilizes engine vacuum from the carburetor to provide the additional spark advance required under part-throttle operation. The vacuum unit contains a spring-loaded diaphragm connected by linkage to the breaker plate. The spring-loaded side of the diaphragm is airtight and connected by tubing to the carburetor.

At idle speed, or as the throttle is opened, vacuum acts on the diaphragm and causes it to rotate the breaker plate in the distributor. Older models were made to allow the vacuum unit to rotate the distributor housing in relation to the shaft.

The amount of advance is proportional to the amount of vacuum. The vacuum unit controls advance at low speed (below approximately 700 rpm) when vacuum is high at the vacuum port in the carburetor. As engine speed increases, both advance units work together during various engine speed and load conditions, and engine spark is controlled to provide maximum power and economy.

TRANSISTORIZED IGNITION CIRCUITS

The transistorized ignition was developed to eliminate some of the problems encountered in conventional systems. The conventional ignition used a fairly high current flow through the points, resulting in arcing and pitting of the contacts as they opened and closed. At the same time, wear of the rubbing block on the movable contact caused the dwell to change and alter the coil saturation period. This created the need for frequent adjustment of the points.

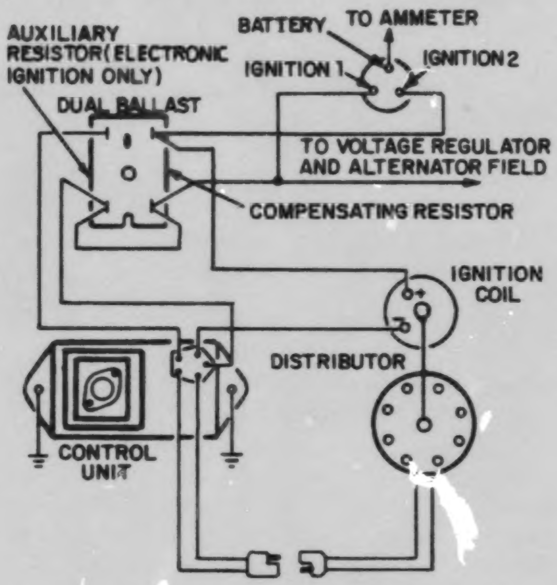
Early models of transistorized ignitions eliminated the condenser and reduced the current to the contacts from approximately 5 amperes to less than 1. This type of ignition improved point life considerably, but the problem of wear on the movable contact rubbing block still remained.

The transistor ignitions in use today have no contact points. A toothed rotating piece has replaced the distributor cam, and a pickup coil and magnet are used in place of the contacts. Figures 7-13 and 7-14 illustrate the type most commonly encountered

The rotating piece is attached to the distributor shaft and has equally spaced teeth, one for each cylinder. The appearance of the rotating piece and its trade name varies with each manufacturer. It may be called a RELUCTOR, ARMATURE, TIMER CORE, or TRIGGER WHEEL.

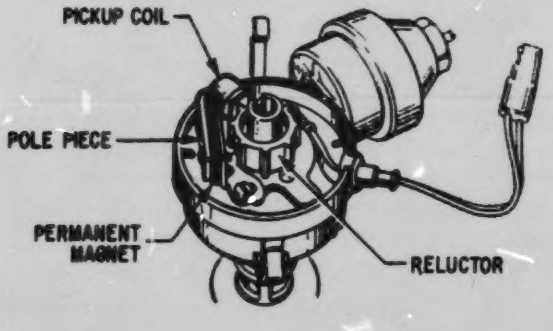
The pickup coil and magnet are positioned in relation to the rotating piece in such a manner that the magnetic field is disturbed each time a tooth passes the magnet. The disturbance of the magnetic field causes a very small current pulse to be induced in the pickup coil. This pulse is used to trigger the transistor in the control unit (amplifier or control module in other designs).

The transistorized circuitry in the control unit either lowers or stops primary current through the ignition coil windings, causing the high voltage spark in the secondary circuit. The transistor in the control unit, which causes this intermittent current flow, is a solid metallic device that allows current to pass until a very small relay current is used to interrupt the normal flow. This action is instantaneous and accomplished electronically so that no movement of the parts is needed. The remaining parts of these ignition systems are similar to the conventional ones discussed earlier.


AUXILIARY RESISTOR(ELECTRONIC IGNITION ONLY)
BATTERY
TO AMMETER
IGNITION 1
IGNITION 2
DUAL BALLAST
TO VOLTAGE REGULATOR AND ALTERNATOR FIELD
COMPENSATING RESISTOR
IGNITION COIL
DISTRIBUTOR
CONTROL UNIT

81.529

Figure 7-13.—Transistorized ignition circuit wiring diagram.


PICKUP COIL
POLE PIECE
PERMANENT MAGNET
RELUCTOR

2.526

Figure 7-14.—Distributor used with transistorized ignition.

Most transistorized ignition systems operate with a higher secondary voltage than the conventional ones. This higher voltage is necessary with the leaner fuel mixtures used in modern engines. Higher voltages are necessary to provide a strong enough spark to ignite the mixture with exhaust circulation incorporated into the engine's system.

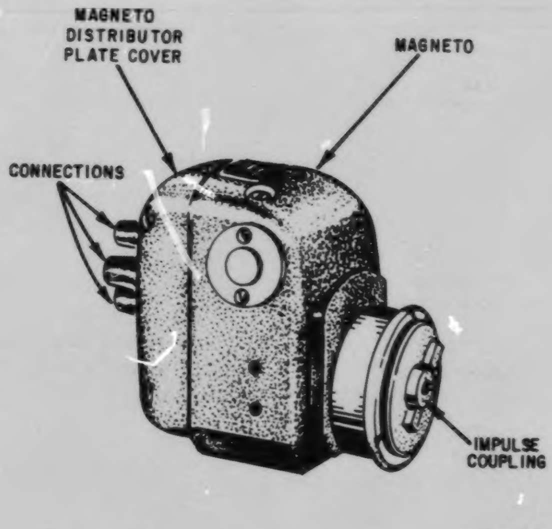
Dwell is electronically controlled in the transistorized ignition and cannot be changed by adjustment. It can be checked with the aid of an ignition scope tester. Two manufacturers provide an adjustment in the distributor during initial assembly. This adjustment should remain stable as long as the components are not changed due to failure. For this reason these ignitions are considered adjustment-free.

There are several kinds of transistor ignition systems. They may vary in design but their operating principles are similar. The main difference is that in newer systems the transistor is triggered by a magnetic pulse generator in a special distributor instead of by contact points.

If you ever need to make repairs to a transistor ignition system, consult the manufacturer's manual and troubleshooting chart. In these systems, one flash of current in a reverse polarity may damage some parts of the system beyond repair.

MAGNETO IGNITION SYSTEM

The magneto (fig. 7-15) used for ignition is a self-contained unit. With the exception of the


MAGNETO DISTRIBUTOR PLATE COVER
MAGNETO
CONNECTIONS
IMPULSE COUPLING

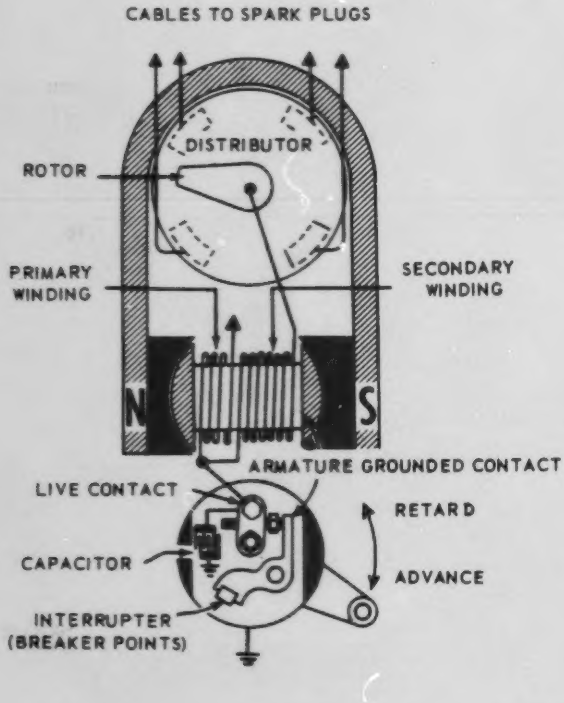
81.139

Figure 7-15.—Automotive magneto.

spark plugs and the wires leading to them, the magneto includes or substitutes for all the units usually found in the battery-ignition system. THE MAGNETO PROVIDES ELECTRICITY FOR IGNITION ALONE AND IS PRIMARILY USED ON SMALL ENGINES THAT ARE STARTED BY HANDCRANKING.

Figure 7-16 shows a horseshoe magnet and the pole pieces that produce a magnetic field. The primary and secondary windings are wound on an armature which rotates within the magnetic field. As the armature revolves, an alternating current of low voltage is generated in the turns of the wire. When this current reaches its highest value, the breaker points open, and high-tension current is induced in the secondary winding, as in the battery-ignition system. The high-tension current is then directed to the magneto distributor and on to the spark plugs in the proper firing order.

As a simple form of electric generator, the magneto produces its own current, thus eliminating the need of a battery in the ignition system.



81.140

Figure 7-16.—Circuits of a high tension magneto.

Types of Magnetos

There are several types of present-day magnetos that differ in magnetic circuits and in the way in which the low-tension current is induced. The ROTATING ARMATURE-TYPE magneto, just described, is the oldest and the one commonly used for automotive equipment. It generates low-tension current on the principle of rotating windings and a stationary field. In the INDUCTION TYPE OF MAGNETO, the windings are stationary and the magnets rotate.

Coming-in Speed

The magneto must be turned at higher than a minimum speed to generate a primary current with enough strength to start the engine and keep it running. This speed will vary with different types of magnetos; the average is about 100 revolutions per minute, and is called the COMING-IN speed of the magneto.

In starting the engine, it is difficult to rotate the crankshaft fast enough to produce this coming-in speed of the magneto. An impulse coupling is used to obtain an initial starting current from the magneto.

Impulse Coupling

The impulse coupling is mounted between the magneto drive from the engine and the magneto-driven shaft. It consists of a spring and ratchet drive. When the engine is turned over by the handcrank, the spring in the device is wound up against a ratchet or trigger arrangement. As the piston reaches firing position, the trigger releases automatically. The spring, which is connected to the magneto-drive shaft, pulls it with enough speed to produce current for one firing. The operation continues until the engine fires and starts to run. As the engine speed increases, the impulse coupling locks out and the magneto is driven normally.

IGNITION SYSTEM MAINTENANCE

Both battery and magneto ignition systems will malfunction from faulty condensers, points, or ignition coils. Ignition troubles also result from loose or broken connections caused by abrasion and vibration during normal engine operation. Unless the engine stops entirely on the job, trouble indications are reported by the driver and the equipment is turned in to the shop for repairs.

Unless the trouble is known, a systematic procedure should be followed to locate the cause. Trace the ignition wires for grounds, shorts, and open circuits. Remember, the electric current follows the path of least resistance, and it will not flow if the resistance of the circuit is too great. Bare wires, loose connections, and corrosion are found through visual inspections.

A faulty condenser or coil cannot be determined by visual inspection and must be TESTED USING SPECIAL EQUIPMENT. A partly discharged battery will affect the operation of the ignition system, and is most noticeable when you try to start the engine. The hydrometer or a high-rate discharge tester is used to test the battery. In the field, a discharged battery can be detected by checking the operation of other electrical units to which it supplies power.

In servicing transistorized ignition circuits, make sure you closely follow any testing and troubleshooting procedures recommended by the manufacturer. In the absence of the manufacturer's procedures, the following procedures will apply generally to all transistorized ignition circuits.

The secondary wiring should be handled with care to prevent any possibility of damage to the internal conductors. A higher voltage is used in the secondary circuit and, as a result, more attention to these cables is required. Normal service consists of an inspection of the wiring and cleaning or changing the spark plugs. Should you have to check the secondary circuit for a spark at the spark plug, hold the lead approximately 1/4 inch from a good clean ground on the engine block with a suitably insulated tool. This will prevent the possibility of shock, or bleed off of the high voltage to ground elsewhere through the cable's insulation. Use care not to ground any of the interconnecting wiring of the ignition circuit when the switch is on. This could cause damage to the control unit or other portions of the system.

Spark Plugs

Under normal operating conditions, spark plugs (fig. 7-17) wear out due to the destructive action, under intense heat, of sulphur and lead compounds in the fuel and the bombardment of the electric spark on the electrodes. It is reasonable to expect 10,000 miles of useful life from a spark plug which has been cleaned and regapped at regular intervals. However, operating conditions are an important factor

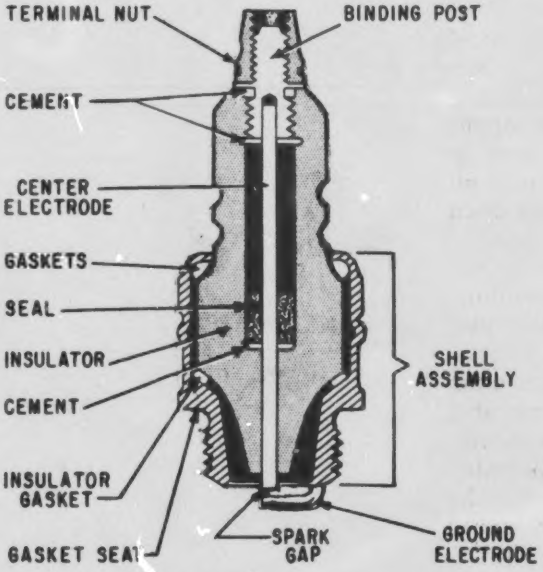


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Figure 7-17.—Sectional view of a typical spark plug.

and life expectancy of the spark plug will vary with the type of service in which the engine is used.

The same type of spark plug used in two engines of the same make and model may frequently show wide variation in appearance. These differences are caused by the condition of the engine, its piston rings, carburetor setting, kind of fuel used, and conditions under which the engine is operated; namely, sustained high speeds or heavy loads, continual low speed, and stop-and-go-driving.

Spark plugs are frequently blamed for faulty engine operation which they do not cause. Replacement of old spark plugs with new ones may temporarily improve poor engine performance because of the lessened demand new plugs make on the ignition system. This cannot permanently cure poor engine performance caused by worn rings or cylinders, weak coil, worn contact points, faulty carburetion or other engine ills.

Spark plug fouling may occur on new engines, or on units which have new piston rings, during the ring seating period. Lower operating speeds with rich carburetor settings are also a factor during initial engine run-in. In these instances, the spark plugs are not worn, and can easily be serviced by abrasive cleaning, regapping, and reinstalling with new seat gaskets. Some problems commonly encountered with spark plugs, due to various operating conditions, are discussed below.

The experienced mechanic finds it extremely helpful, when diagnosing a problem, to remove and examine the appearance of the plug. The appearance of a plug under normal operation conditions is illustrated in figure 7-18. Brown to grayish-tan deposits and slight electrode wear indicate correct spark plug heat range and mixed periods of high and low speed driving. Spark plugs having this appearance may be cleaned, regapped and reinstalled. When reinstalling spark plugs that have been cleaned and regapped, be sure to use a new engine seat gasket if one is required. Some automotive-type spark plugs are beveled and need no gasket.

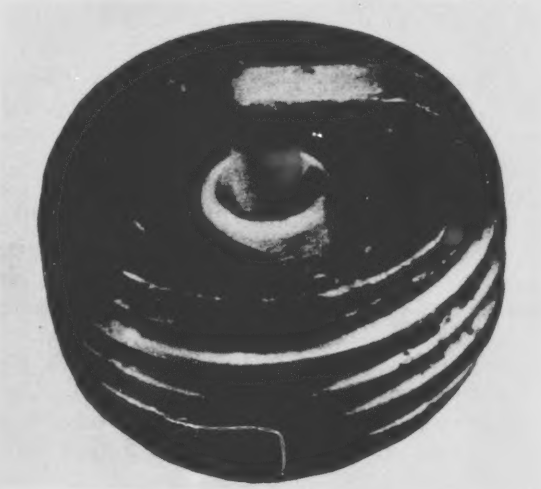

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Figure 7-18.—Normal operation.

Dry, fluffy black carbon deposits (fig. 7-19) may result from overrich carburetion, excessive hand choking, a faulty automatic choke, or a sticking manifold heat valve. Poor ignition output (faulty breaker points, weak coil or

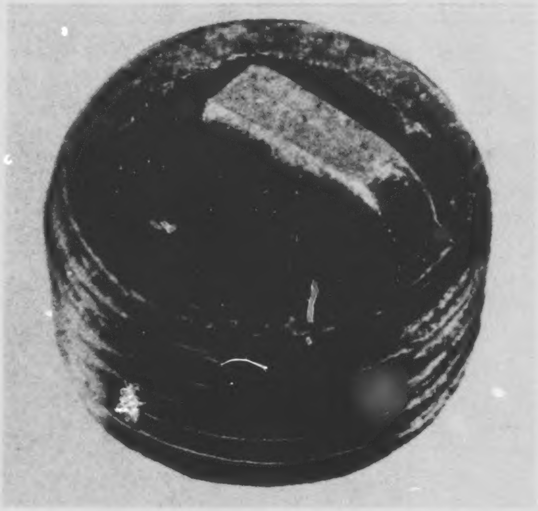

Figure 7-19.—Carbon fouling. 81.445

condenser, worn ignition cables) can reduce voltage and cause misfiring. Excessive idling and slow speeds under light load also can keep spark plug temperatures so low that normal combustion deposits are not burned off. Fouled spark plugs are the result—not the cause—of this problem. Spark plugs having this appearance should be cleaned, regapped, and reinstalled.

Wet, oily deposits (fig. 7-20) with very little electrode wear may be caused by oil pumping past worn rings. Break-in of a new or recently overhauled engine before rings are fully seated may also result in this condition. Other possibilities of introduction of oil into the combustion chamber are a porous vacuum booster pump diaphragm or excessive valve stem guide clearances and/or defective intake valve seals. Usually, plugs which have been fouled with oil can be degreased, cleaned, and reinstalled.

A HOTTER TYPE SPARK PLUG WILL REDUCE OIL DEPOSITS, but too hot a spark plug can cause preignition and, consequently, severe engine damage. An engine overhaul may be necessary in severe cases to obtain satisfactory service.

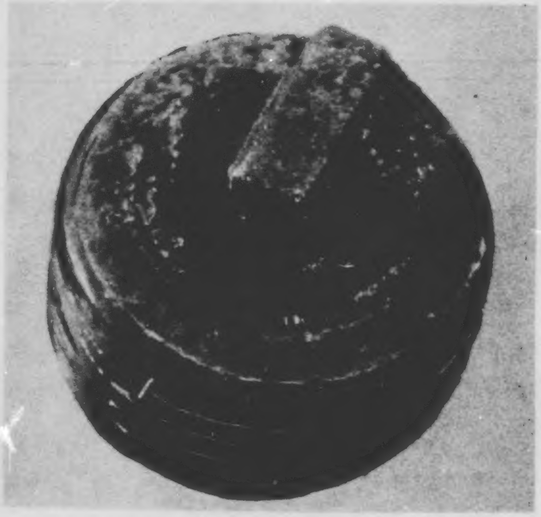

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Figure 7-20.—Oil fouling.

Red, brown, yellow, and white colored coatings (deposit fouling) which accumulate on the insulator are byproducts of combustion and come from the fuel and lubricating oil, both of which today generally contain additives. Most powdery deposits (view A, fig. 7-21) have no adverse effect on spark plug operation; however, they may cause intermittent missing under severe operating conditions, especially at high speeds and heavy load. If the insulator is not too heavily coated, the spark plugs may be cleaned and regapped. Sometimes, even after cleaning, an invisible shunt path remains. The only remedy under such circumstances is to replace the plug.

Most powdery deposits, as shown in view A, have no adverse effect on the operation of the spark plug as long as they remain in the powdery state. However, under certain conditions of operation, these deposits melt and form a shiny yellow glaze coating (view B, fig. 7-21) on the insulator which when hot, acts as a good electrical conductor. This allows the current to follow the deposits instead of jumping the gap, thus shorting out the spark plug. Glazed deposits can be avoided by not applying sudden load, such as wide open throttle acceleration, after sustained periods of low speed and idle operation. It is almost impossible to effectively remove glazed deposits; so, when they occur the plugs should be replaced.

Excessive overheating is evidenced by burned or blistered insulator tips and badly worn electrodes. It is brought on by preignition, cooling system defects, lean fuel-air ratios, low octane fuels, over-advanced ignition timing, improper installation procedures, and stuck closed heat riser valves. (See view A and B, figure 7-22.)

Install a new plug of the recommended heat range after the problem has been corrected.

Sustained high speed and/or heavy load service can produce high temperatures which will cause preignition and, in this instance, a

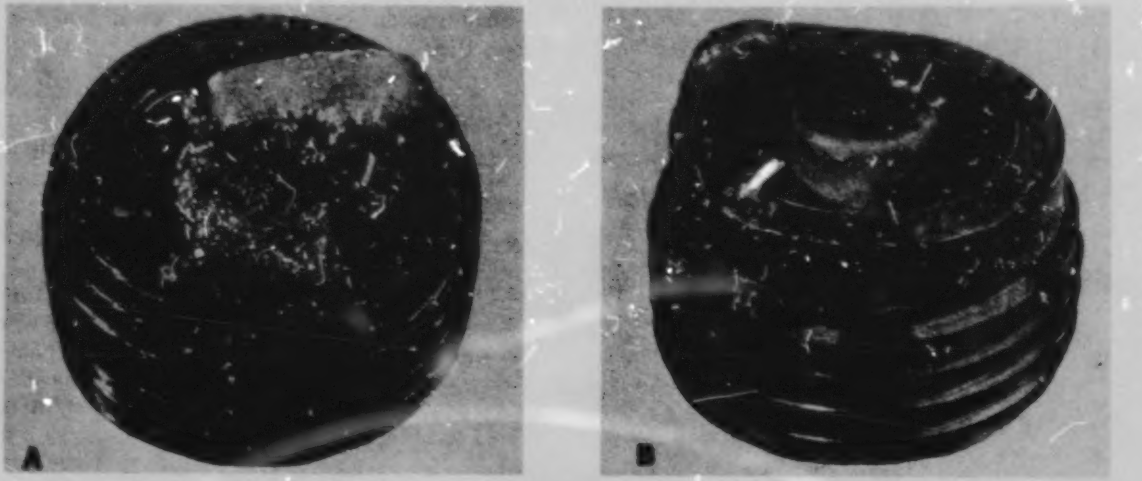

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Figure 7-21.—Deposit fouling.

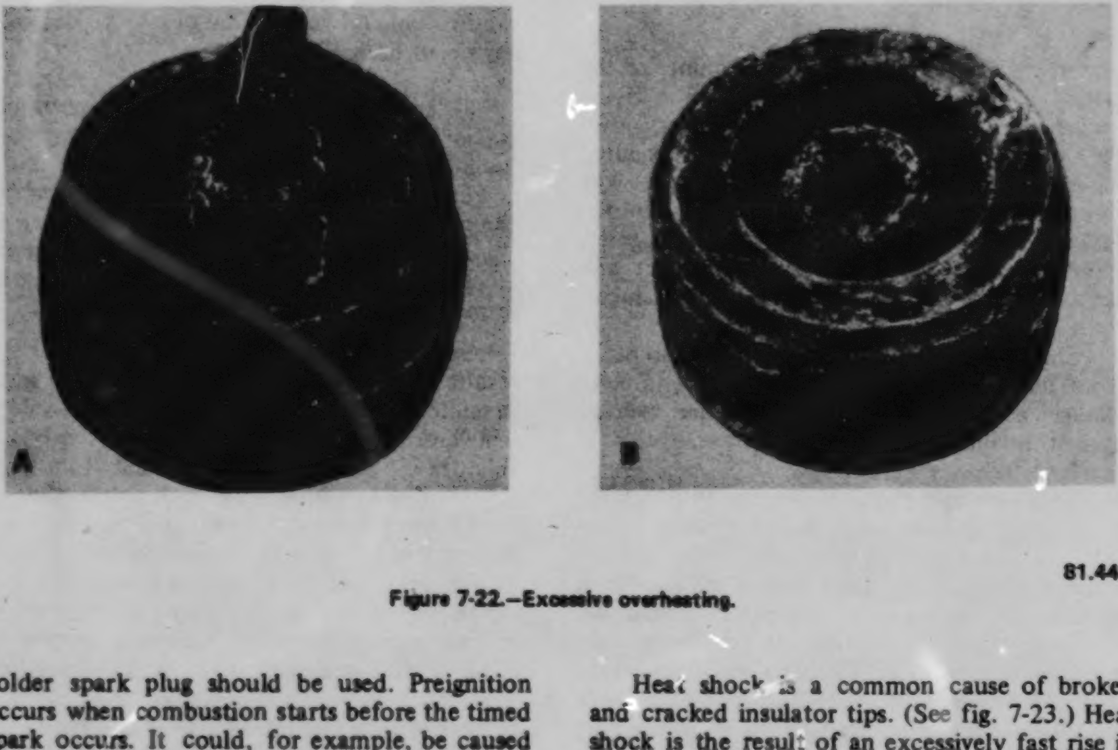

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Figure 7-22.—Excessive overheating.

colder spark plug should be used. Preignition occurs when combustion starts before the timed spark occurs. It could, for example, be caused by a hot carbon deposit in the combustion chamber.

Heat shock is a common cause of broken and cracked insulator tips. (See fig. 7-23.) Heat shock is the result of an excessively fast rise in tip temperature under severe operating conditions. It occurs due to engine detonation

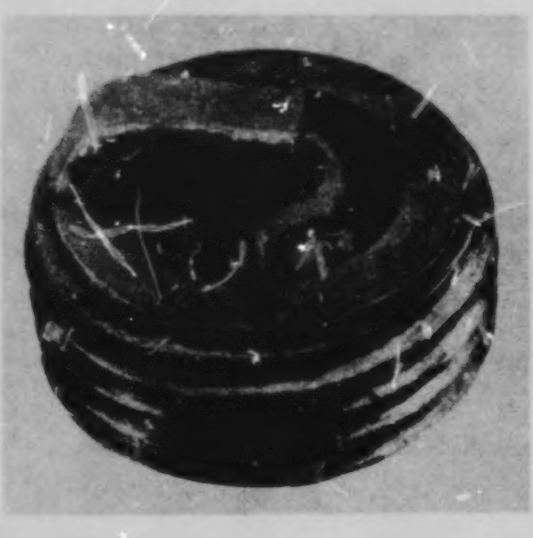

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Figure 7-23.—Heat shock failure.

caused by over-advanced ignition timing, or the use of too low octane fuel. Detonation is the sudden and violent combustion of a portion of the unburned fuel ahead of the normally ignited flame front. Detonation occurs part way through the burning cycle, when the unburned fuel reaches its critical temperature, and ignites spontaneously. The result is severe heat and pressure shock within the combustion chamber.

Chipped and broken insulator tips also result from improper gapping tools or procedures in which excessive or side pressures are exerted against the insulator tip.

Eliminate the cause of trouble and install a new plug of the recommended heat range.

Spark plug overheating caused by poor heat transfer is the result of failure to install the spark plug with sufficient torque to provide good contact between the spark plug and engine seat. (See views A and B, fig. 7-22.) Dirty threads in the engine head which allow the plug to seize before it is actually seated will also cause this condition.

A new spark plug of the recommended heat range should be installed in accordance with specified installation instructions.

Proper gasket compression must be achieved by installing a new plug at the specified torque. No gasket compression with a new plug and engine seat gasket means that little or no force has been applied to the gasket. In actual installation, it is necessary to almost completely compress the gasket to allow proper heat transfer to the engine block. If a spark plug gasket is not tightly seated, leaking combustion gases will cause overheating. This shortens the life of the plug due to excessive wear of the overheated electrodes and, in addition, it may lead to preignition.

NOTE: Proper installation torque may be attained without compressing the engine seat gasket. Thread seizure, due to scaled and deposit-filled threads, may not allow the proper gasket compression. Operation of an engine with this type of installation can result in plug overheating and destruction of either the plug or engine, or both.

In applications where liquefied petroleum gas is the fuel, carbon and lead deposits and fouling are not a problem. The only critical concern is electrode wear. The normal recommendation for liquefied petroleum gas applications is one or two heat ranges colder to increase resistance to electrode wear, thereby prolonging the life of the plug.

Sparking through the insulator to the shell results from a visible or invisible fracture in the insulator caused by careless removal or installation of the spark plug. Frequently, this fracture is not visible as it is located at the upper gasket shoulder inside the shell crimp. (See fig. 7-24.) When testing these plugs in a compression box tester, sparks may be seen around the shell at this point and, in some cases, may also occur across the electrode gap. As tester compression is increased (increasing resistance across the gap), it will spark only through the fracture as this path then becomes the path of least resistance from center wire to shell. There is no remedy for a broken insulator except replacement with a new spark plug.

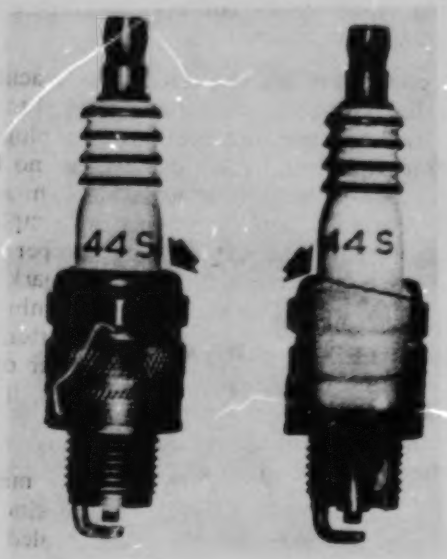

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Figure 7-24.—Result of improper installation or removal of spark plugs.

Before spark plugs are to be removed, their wires should be removed carefully. In removing a spark plug wire, first grasp it by the terminal boot; then twist and pull on the boot at the same time. Do not jerk the wire from a spark plug. Loosen each plug one or two turns, then use compressed air to blow out any dirt around the spark plug hole. This will prevent foreign matter from entering the cylinder.

When cleaning spark plugs by the sandblasting method, use short blasts accompanied by rocking of the spark plug. After sandblasting, use air to remove any sand from the insulator. Next, file the center electrode flat on the end and regap the spark plug to manufacturer's specifications. Spark plugs serviced in this manner will give many additional miles of service. Overblasting and not rocking spark plugs during cleaning results in dirty, damaged insulator tips. Eroded tips change heat range and conductive paths mean fouled plugs, both resulting in poor engine operation.

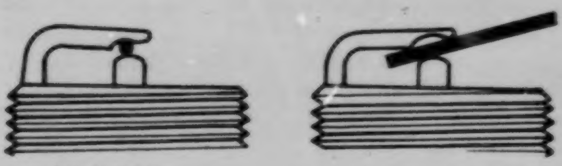
Appreciable gap wear at low mileage usually indicates that the engine is operating under excess loads or that a wrong type of plug (too hot) is being used. Before changing to a cooler type plug, check the heat range with the specification chart. If the plug showing rapid electrode wear is the type recommended, the seat gaskets should be checked. If gasket appearance is satisfactory, install spark plugs at least one step colder.

After several thousand miles of service, the spark plug gap widens and should be regapped. This widening is due to the combined action of intense heat, pressure, and corrosive gases within the combustion chamber together with the spark discharges. If the electrodes have worn so thin that regapping would only add a few hundred miles of satisfactory performance, the plug should be discarded and replaced.

When a plug is removed for cleaning or inspection, it should be regapped as specified by the engine manufacturer. Use a round wire type gage for accurate measurement of gap on used spark plugs. (See view A, fig. 7-25.) A plain flat feeler gage cannot be used to accurately measure the true width of the gap. (See view B, fig. 7-25.)

When regapping a plug, always adjust the side (ground) electrode, because sidewise pressure may crack or break the insulator tip. DO NOT use gapping pliers.

Replace plugs with cracked or broken insulators, or with electrodes badly burned, pitted, or worn so thin that the short period of additional good performance they might render would not justify their installation. If the majority of the plugs in an engine are worn out, replacement of the entire set is recommended.


(A) CORRECT (B) INCORRECT

81.451

Figure 7-25.—Measuring gap.

Distributor

By a visual inspection you can tell whether the distributor points need renewing. If pitted or burned, they should be replaced. Points should never be filed except in an emergency.

When you remove the distributor cap, inspect the points, where applicalbe, to insure that they are clean. Inspect the cap carefully for cracks or other damage. A crack reaching the center terminal may permit the high-tension current from the coil to ground through the distributor body. Check the rotor for cracks, corrosion, and burned terminals.

The distributor shaft should be checked to insure its bushings are not worn excessively. Worn bushings result in loss of power because of the fluctuation in ignition timing. To check, grasp the top of the shaft and attempt to move it sideways in relation to the distributor housing. If movement is noticeable, you should disassemble the distributor and install new bushings.

To remove the distributor shaft, remove the circuit breaker plate. (On distributors that have the mechanical advance above the breaker plate, the plate will not come off until the shaft is removed.) The plate is held in position by screws or clips. On distributors that have a vacuum advance unit, you must remove this unit prior to removing the circuit breaker plate. Next, remove the gear from the drive end of the distributor. Once the gear is removed, the shaft can be withdrawn from the housing. The bushings are not normally available and the housing and shaft must be taken to the machine shop to have new bushings made and installed.

When reassembling the distributor, make sure that the drive gear hole lines up with the hole in the distributor shaft. These holes are offset and should you attempt to force the pin without proper alinement, the gear or shaft may be damaged.

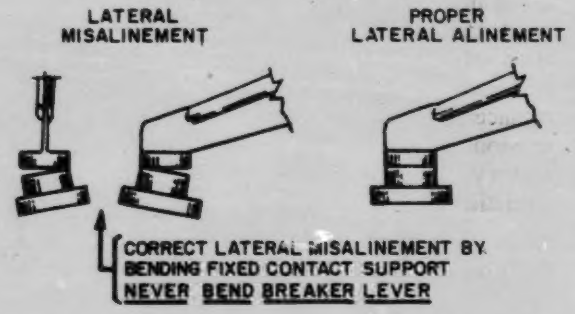
It is recommended in most shops to replace the condenser when the points are replaced. Although the outward appearance of condensers is nearly always the same, their capacity varies. Make sure you install the correct condenser; otherwise, there will be excessive transfer of material from one contact to the other, shortening contact point life.

If condensers are suspected of being faulty, check them using a condenser tester. Be sure you follow the instructions for testing condensers as given by the manufacturer of the tester you are using. It is advisable to make a series resistance test after installing a new condenser. This test may indicate other defects within the distributor, such as loose or corroded connections, ground, or shorts.

INSTALLING CONTACT POINTS is a comparatively simple procedure but must be done with precision and care in order to achieve good engine performance and economy. Make sure the points are clean and free of any foreign material.

Proper alinement of the contact points is extremely important. (See fig. 7-26.) If the full faces of the contacts do not touch each other, the heat generated by the primary current cannot be dissipated and rapid burning takes place. The contacts are alined by bending the stationary contact bracket only. NEVER BEND THE MOVABLE BREAKER ARM. Make sure the breaker arm rubbing block rests flush against the distributor cam. A small amount of approved lubrication should be placed on the cam to prevent rapid wear on the rubbing block.

Contact spring tension must be within the manufacturer's specifications. If the tension is


LATERAL MISALINEMENT
PROPER LATERAL ALINEMENT
CORRECT LATERAL MISALINEMENT BY BENDING FIXED CONTACT SUPPORT NEVER BEND BREAKER LEVER

81.452

Figure 7-26.—Point alinement.

too weak, the points will bounce or float (tend to remain open at high speed.) As the points bounce, they interrupt the primary current and do not allow the saturation of the ignition coil that is necessary to develop the high voltage needed to fire the spark plugs. If the spring tension is too high, the rubbing block will wear prematurely.

The terms DEGREES OF DWELL and DWELL both refer to the number of degrees the cam rotates while the points are closed in each cycle. Contact point opening has a direct effect on degrees of dwell. As the point opening is increased the degrees of dwell decrease; and, as the point opening is decreased the degrees of dwell increase. The cam angle can be checked by using a dwell meter. First adjust the point opening with a feeler gage; then check the point dwell with the dwell meter to see if the readings are within the manufacturer's specifications. Some engine tuneup charts list only degrees of dwell rather than point setting. A dwell meter must be used for correct setting of the points. If the cam angle is not within the manufacturer's specifications, inspect the distributor for a worn breaker plate, worn cam, shaft, worn bearing or bushing, and bent breaker arm.

The external contact point adjustment on some Delco-Remy distributors makes it possible to adjust the dwell with the engine operating. To do this, operate the engine at idling speed. Raise the window on the distributor and insert a hex wrench in the point adjusting screw. With the dwell meter attached, rotate the adjusting screw until the specified dwell is obtained. On this type of distributor, the contact point set is replaced as one complete assembly. The replacement set has the breaker level spring tension and point alinement adjusted at the factory. Only the point opening requires adjusting after replacement.

Ignition Timing

Standard setting of timing as recommended by the manufacturer is designed to obtain maximum power, performance and economy under average driving conditions. There are timing marks on either the flywheel or the crankshaft vibration damper.

To time the engine, clean all the grease and dirt from the timing mark and reference pointer. Draw a chalk line over the timing mark to make it easier to see. Connect the timing light to the high tension lead of the No. 1 spark plug and the power leads to the power supply. Connect a tachometer, if available, to the primary circuit of the distributor. Warm the engine to normal operating temperature and adjust the idle speed. Remove the distributor vacuum line and plug the opening to the carburetor or manifold. Aim the timing light flashes at the timing mark and reference pointer. If the timing mark and pointer do not line up, loosen the distributor and turn it in its mounting until the timing mark is in alinement with the pointer, then secure the distributor. You should then check to see if the automatic advance mechanism is working. This can be done by keeping the timing light flashes aimed at the timing mark and gradually increasing the engine speed. If the advance mechanism is working, the timing mark should gradually move away from the pointer. If the timing mark fails to move as the engine speed is increased, or if it hesitates and then suddenly jumps, the advance mechanism is not functioning properly and should be repaired. Replace the distributor vacuum line and see if the timing still conforms to the manufacturer's specifications. If the timing is NOT advanced when the vacuum line is connected and the throttle is opened slightly, the vacuum advance unit or tubing is defective.

Waterproof Ignition Systems

Since tactical vehicles sometimes operate under very wet conditions and must be able to ford fairly deep waters, it is necessary to waterproof the ignition system. Waterproofing means that the system must be so watertight that the components continue to function normally even while totally immersed.

The distributor and ignition coil are sealed in a common housing and enclosed by a common cover. This unit also has a means of ventilating the distributor, thus preventing the condensation of water and the formation of harmful chemicals. The ventilation is accomplished by connecting two tubes to the distributor, one leading to the air cleaner (from which clean air can be obtained) and the other to the intake manifold. The intake manifold vacuum causes air to pass through the distributor from the air cleaner, thus keeping the distributor well ventilated.

The various leads in the ignition system are enclosed in a watertight conduit. This conduit prevents moisture from getting to the leads with resultant insulation deterioration.

The repair and maintenance of waterproof ignition systems are similar to conventional systems. The same tests and checks should be made, but in most cases special adaptors for use on the waterproof connections are furnished with the test equipment. When replacing any connection on the waterproof system, make sure the gaskets and seals are in good condition and waterproof.

LIGHTING CIRCUIT

The lighting system of automotive vehicles includes the headlights, tail lights, dash lights, dome lights and signal and warning lights.

The manufacturer has provided your equipment with an electrical system which includes all the lighting circuits required for the job the equipment is designed to do. Some are more complicated than others but include the same basic units. The most important of these, which you will find in almost all equipment, are the lights (lamps), switches, and fuses or circuit breakers.

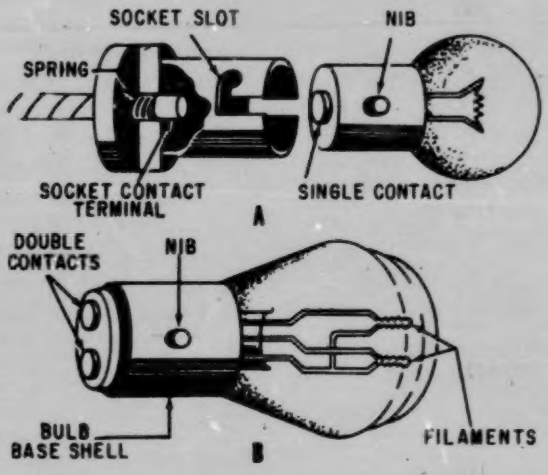
LAMPS AND BULBS

When operating at night, heavy duty (large) trucks and buses are lit up like a Christmas tree. In addition to the headlights and tail lights, which are the minimum running lights required by law for all vehicles at night, these trucks and buses require indicating lights, sometimes called position lights. These lights show the length, height, and width of the vehicle. The auxiliary lights are convenience lights for the operator and passengers. Convenience lights include dash or panel lights and dome lights.

Each group of lights in a branch circuit of the lighting system is protected by a fuse or circuit breaker, and is provided with a switch. Each light in the group is provided with one or more light bulbs which is rated for the particular circuit.

Light bulbs used in Navy equipment are made to operate on a low voltage current of 12 or 24 volts, depending upon the voltage of the electrical system used. Bulbs are rated as to size by the candlepower of light they produce. They range from small one-half-candlepower bulbs to large 50-candlepower headlight bulbs. The greater the candlepower of the bulb, the more current it requires when lighted. Bulbs are identified by a number on the base.

When you replace light bulbs in a vehicle, be sure the new bulb is of the proper rating. With the exception of the sealed beam bulbs, the other bulbs within the vehicle will be of the single or double contact with nibs to fit bayonet sockets, as illustrated in figure 7-27.



29.104

Figure 7-27.—(A) Single contact bulb; (B) Double contact bulb.

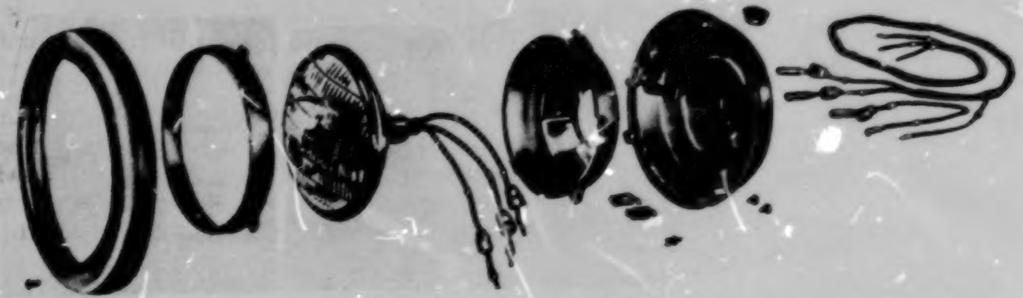


Figure 7-28.–A typical sealed beam headlamp assembly.

The sealed beam light is actually a large bulb (fig. 7-28). The bulb consists of a lens, two filaments, and its own integral glass reflector. One of the filaments is used as the upper, or high, beam for country or open highway driving, and the other is used as the low beam for oncoming highway traffic or city driving. When either of these filaments burns out, the complete unit must be replaced.

Most vehicles (commercial) have four sealed beam headlights, two on each fender (fig. 7-29). The outboard lights are typical sealed beam lights as described above and are marked with the numeral 2 molded on the upper portion of the glass lens. The inside, or inboard, headlights have one filament and are marked with the numeral 1 molded on the upper portion of the glass lens (fig. 7-29). The inboard lights operate with the high beams of the outboard headlights for country driving. For city driving, or for meeting oncoming open highway traffic, the low beams of the outboard headlights are used; the inboard lights are out when the low beams are on.

HEADLIGHTS

Headlights are tested for intensity and aim. The focus of sealed beam lights is pre-set at the time they are manufactured. Therefore, your concern will be the aiming and the intensity of the headlights. Aiming is accomplished as indicated in figure 7-29. Traffic laws require that headlights be of sufficient intensity to reveal persons and objects for a distance of at least 350 feet ahead. The minimum output established by most States to fulfill this requirement for upper and lower beam is 5,000 and 3,500 candlepower, respectively.

Your shop may be provided with a meter that measures the headlight intensity (candlepower). This meter can be used in conjunction with a screen for aiming the lights.

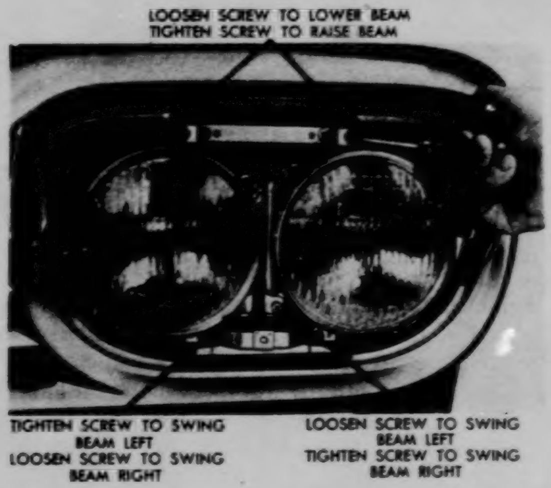

LOOSEN SCREW TO LOWER BEAM
TIGHTEN SCREW TO RAISE BEAM
TIGHTEN SCREW TO SWING BEAM LEFT
LOOSEN SCREW TO SWING BEAM RIGHT
LOOSEN SCREW TO SWING BEAM LEFT
TIGHTEN SCREW TO SWING BEAM RIGHT
2.124

Figure 7-29.–Typical dual installation of sealed beam headlights.

Headlight testers that can be used for aiming, as well as for measuring, the intensity of the light also are available.

Using Screen For Aiming Headlights

Although a meter may not be available for measuring headlight intensity, you should nevertheless insure that the headlights of vehicles are aimed correctly; a headlight that is not aimed properly may blind drivers of oncoming vehicles.

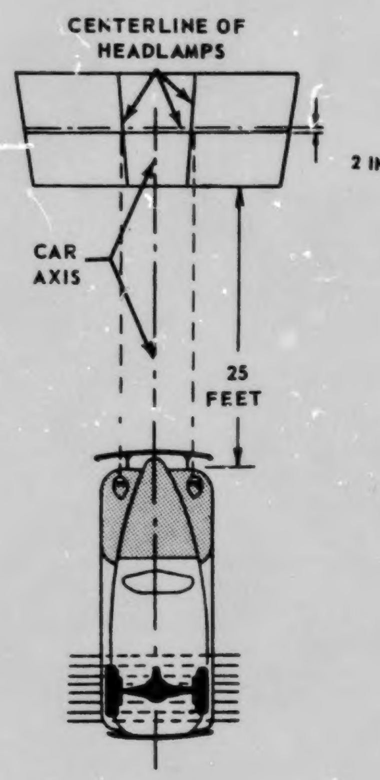
A screen can be made that will enable you to test headlight aim. When making a screen you should put only the headlight center level and vehicle axis lines on it. These lines can accommodate all types of vehicles.

The screen for aiming headlights (fig. 7-30) should be no less than 10 feet wide and 42 inches high. When it is mounted on a frame or easel with casters, the screen should be no more than 12 inches from the floor surface.

By moving the screen up or down, the headlamp level line can be made to conform with the measured height of any headlamp being tested. Moving the vehicle or the screen left or right will accomplish accurate alinement with the vehicle axis line. After these basic steps, vertical lines conforming to the distance between the centers of the headlamps can be added either by line or tape. The vertical lines should intercept the headlamp level line at a point measured from the vehicle axis line exactly one-half the distance between the lamp centers.

To comply with regulations of most localities the screen should be placed 25 feet ahead of the headlight. Make sure all tires on the vehicle are properly inflated. The vehicle should have a full tank of fuel (to compensate for weight) and no one other than the operator should be in the vehicle.

Before beginning the actual tests or adjustments, check the lighting regulations for your particular location. Illustrations of proper light patterns and suggestions for inspecting parts of the headlight assembly are often included in regulations available from the local traffic authorities. Adjustments for aiming headlights may differ for various makes of vehicles. Check the manufacturer's manual for the particular make and model of vehicle being inspected.

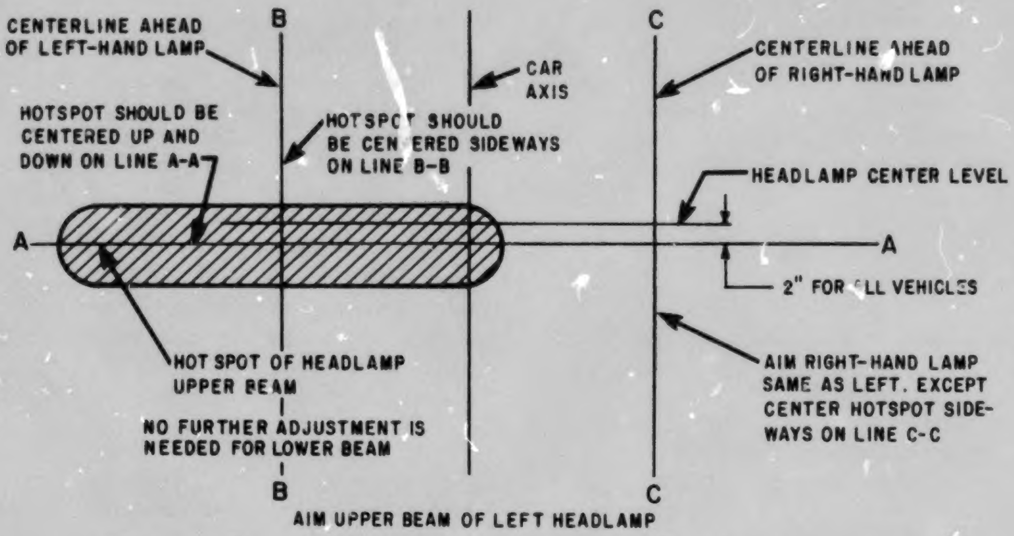


2.125

Figure 7-30.—Screen for checking aim of headlights.

When aiming the headlights of a vehicle using the 7-inch sealed beam light unit, remember that the pattern of the upper or driving beam is the one that will be aimed. The 7-inch lamp is designed so that when the upper beam is aimed correctly the lower or passing beam will also be aimed correctly. Cover the lamp that is not being aimed so that one beam will not interfere with the other.

The accepted driving beam pattern for passenger vehicles will show the high-intensity portion (hotspot) of the light rays centered on a


CENTERLINE AHEAD OF LEFT-HAND LAMP
B
CAR AXIS
C
CENTERLINE AHEAD OF RIGHT-HAND LAMP
HOTSPOT SHOULD BE CENTERED UP AND DOWN ON LINE A-A
HOTSPOT SHOULD BE CENTERED SIDEWAYS ON LINE B-B
HEADLAMP CENTER LEVEL
A
A
2" FOR ALL VEHICLES
HOT SPOT OF HEADLAMP UPPER BEAM
NO FURTHER ADJUSTMENT IS NEEDED FOR LOWER BEAM
AIM RIGHT-HAND LAMP SAME AS LEFT. EXCEPT CENTER HOTSPOT SIDEWAYS ON LINE C-C
B
C
AIM UPPER BEAM OF LEFT HEADLAMP

2.126

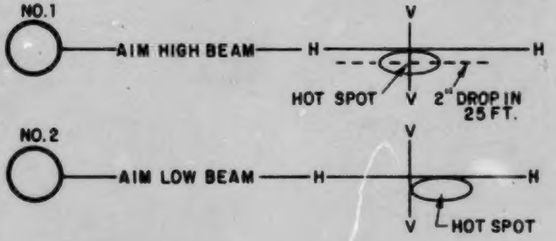
Figure 7-31.—Accepted beam pattern for aiming passenger vehicle headlights.

horizontal line which is 2 inches below the center or horizontal reference line on the screen. (See fig. 7-31.) This means that there will be a 2-inch drop of the light beam for every 25 feet of distance from the bulb.

Headlights on trucks present a special problem because of the effect of a heavy load. At the same distance of 25 feet, truck headlights should be aimed so that none of the high-intensity portion of the light will project higher than a level of 5 inches below the center of the lamp being tested. This is necessary to compensate for the variations in loading. Bus headlights present a somewhat similar situation except that the effect of a load is not quite as great.

Some large equipment will have the lamp centers higher than the testing screen. In this case, place the screen 75 feet ahead of the lights and adjust the horizontal line on the screen to 42 inches; the top of the hotspot of the beam of light should not be above the horizontal line on the screen.

When using a screen for aiming the headlights on a vehicle that uses the 4-headlight system, adjust the hotspots of the No. 1 (inboard) lamps so that they are centered on the vertical lines 2 inches below the horizontal line. (See fig. 7-32.) The low beams of the No. 2 (outboard) lamps are aimed so that the hotspot does not extend to the left of straight ahead or extend more than 6 inches to the right of straight ahead. The top of the hotspot of the No. 2 lamp is aimed at the horizontal line, as shown in figure 7-32. When the low beams of the No. 2 lamps are properly adjusted, the high beam will be correct.


NO.1
AIM HIGH BEAM
H
H
V
V
HOT SPOT
2" DROP IN 25 FT.
NO.2
AIM LOW BEAM
H
H
V
V
HOT SPOT

2.127

Figure 7-32.—Accepted beam pattern for 4-headlight system.

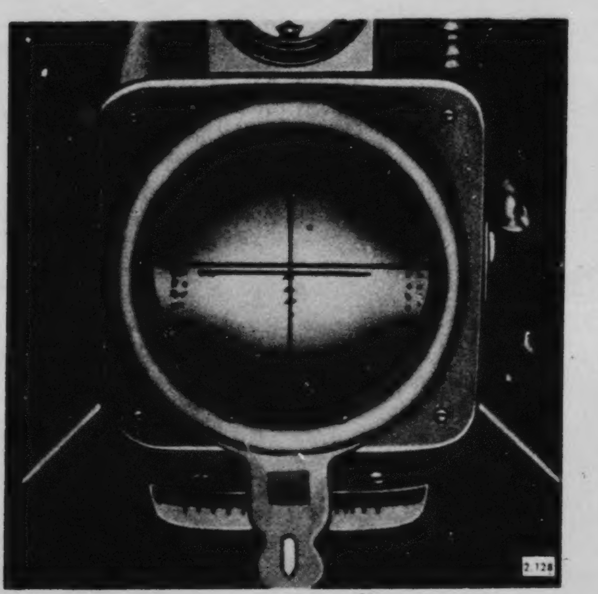
Using Headlight Tester For Checking Headlights

When using a headlight testing device for checking beam patterns, measuring beam candlepower, and adjusting headlamps, follow the instructions furnished by the manufacturer. Headlight testers differ considerably in design and operating characteristics; therefore, correct instructions for using one tester will not be correct for another.

The headlight tester may be one that is permanently installed on a track or it may be portable. The floor where the permanently installed tester is used should be reasonably level, and in case there is a slope to the floor the tester must be adjusted to this slope. Since a permanently installed tester will always be used in the same location, it can be adjusted to the slope of the floor when installed. On the portable-type tester, the testing unit must be set to the slope of the floor for each location where it is being used.

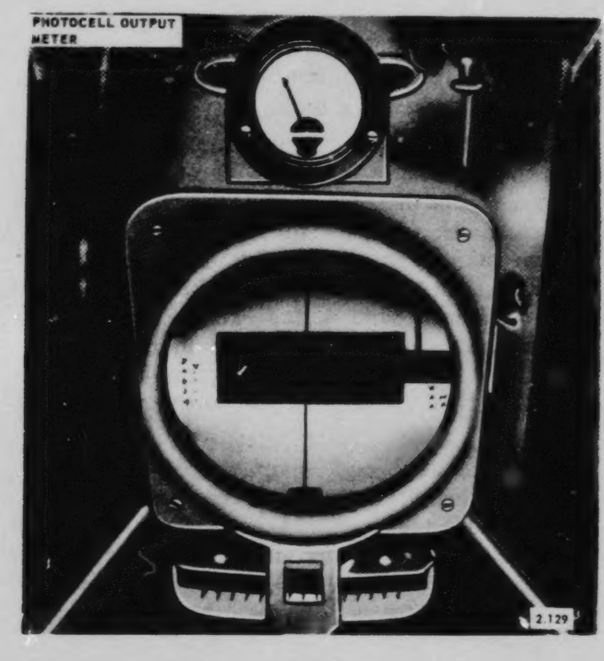
Figure 7-33 shows a beam pattern being checked on a Bear headlight tester screen. Figure 7-34 illustrates the same machine being used to obtain a candlepower reading of the headlamp beam. Notice the image of the photoelectric cell on the screen and the reading on the output meter. To check candlepower in this manner, simply turn the small handle mounted on top of the testing unit to the left until the photocell touches the glass holding the screen. Then raise and lower the photocell with the same handle until the highest reading is obtained on the output meter. Be sure the hotspot of the light beam is centered on the vertical line before attempting to take a candlepower reading.

If the beams are aimed properly but do not meet the required candlepower, check the wires and connections in the circuit. Poor light from sealed beams is often the result of a loose connection, bad ground, or use of undersized wire. Any one of these increases the resistance



2.128

Figure 7-33.—Checking beam pattern with Bear headlight tester.



2.129

Figure 7-34.—Measuring beam candlepower with a Bear tester.

of the circuit. If you can't find a fault in the wiring or connections, replace the sealed beam unit.

CIRCUIT BREAKERS, SWITCHES, AND FUSES

Most switches are placed on the instrument panel close to the driver, or operator. The fuses or circuit breakers can usually be found behind the instrument panel on a fuse block, as shown in the wiring diagram in figure 7-35.

The light control switch of the push-pull type, shown in figure 7-36, is a common type of switch and usually controls three circuits as illustrated. If you must replace such a switch, be sure you tag your wires before removing them, or change them from the old to the new switch one at a time. Removing the grounded battery terminal before making an installation of this kind will prevent blowing out fuses.

Light switches are placed in series with the circuit they control between the source of current and the light bulb. Be sure the light switch terminals are not grounded to any part of the frame or body to which they are fastened for support. If grounded, the lights in the circuit will not burn. STOP LIGHT SWITCHES, in which the contacts close automatically when the brake pedal is depressed, are of two types: pressure and mechanical.

The most commonly used stop light switch is the pressure type, which closes by either air or hydraulic pressure acting on a diaphragm inside the switch. This switch is usually attached to the brake valve (on airbrake systems) or the master cylinder.

The mechanical type of stop light switch is mounted under the dash on the brake pedal support bracket. This switch operates mechanically by spring pressure when the brake pedal is depressed. You will find the mechanical type of switch frequently used on all vehicles with dual braking systems (independent front and rear systems).

Fuses are safety devices placed in electrical circuits to protect wires and electrical units from a heavy flow of current. Each circuit, or at least each individual electrical system, is provided with a fuse that has an ampere rating for the maximum current required to operate the units. The fuse element is made from metal with a low melting point, and forms the weakest point of the electrical circuit. In case of a short circuit or other trouble, the fuse will be burned out first and open the circuit just as a switch would do. Examination of a burned out fuse usually gives an indication of the problem. A discolored sight glass indicates the circuit has a short either in the wiring or one of its components. If the glass is clear, the problem is an overload in the circuit.

Be sure, when replacing a fuse, that it has a rating equal to the one burned out, and that the trouble which caused the failure has been found and repaired.

WIRING CIRCUITS

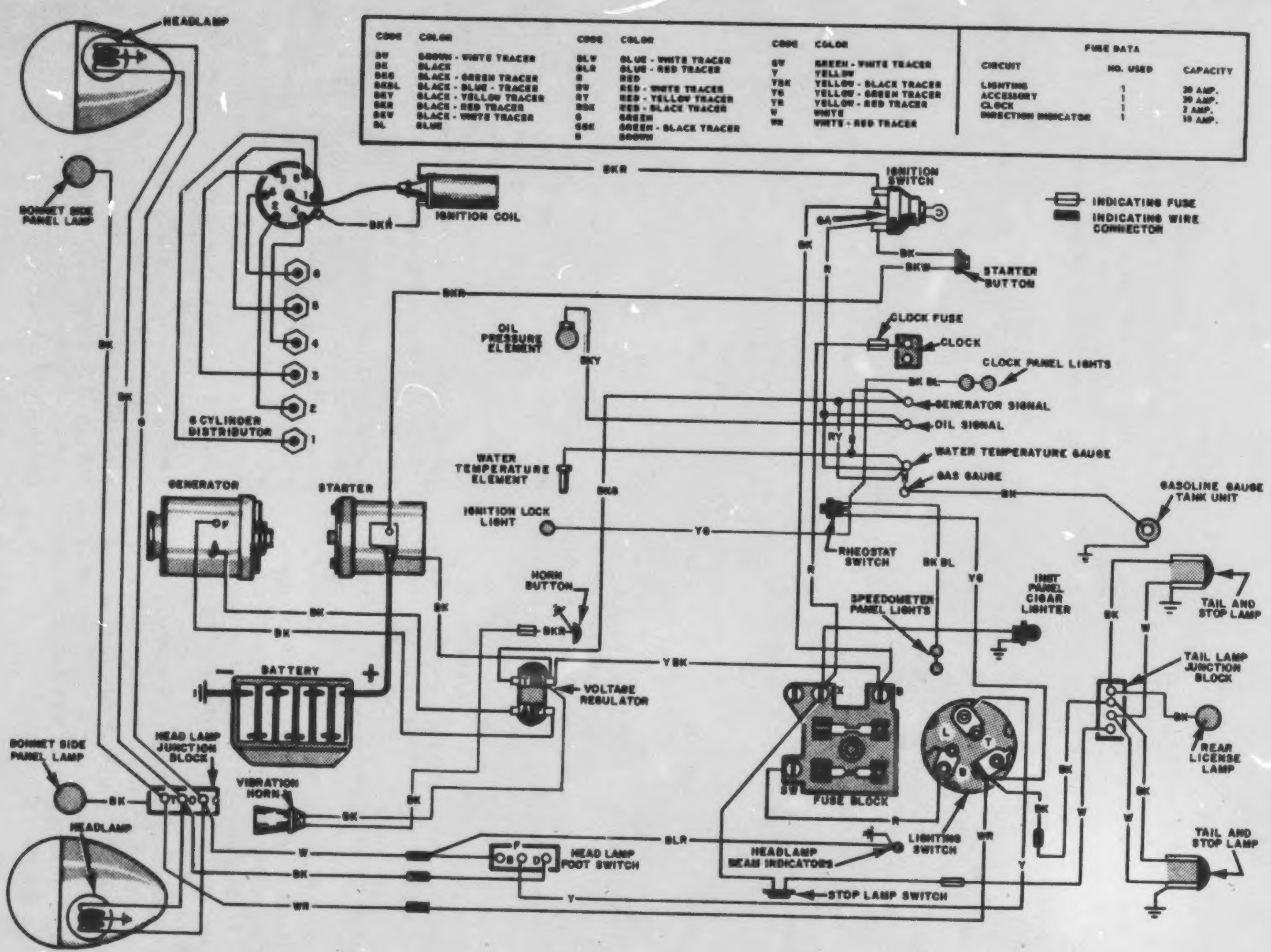
Among your many duties will be the job of maintaining and repairing automotive vehicle electrical systems. All vehicles are not wired in exactly the same manner; however, once you thoroughly understand the circuit of one vehicle, you should be able to trace an electrical circuit in any vehicle.

ELECTRICAL TROUBLES

In the maintenance and repair of electrical systems, troubleshooting is the biggest job. When the lights go out, or the electric starter will not work, you cannot always expect to find the trouble in a dead storage battery or faulty generator. Most troubles are due to other causes, usually bare wires or poor connections.

Each piece of equipment is provided with an operations and maintenance manual. In the manual you will find wiring diagrams, which may not be as complicated as the one shown in figure 7-35. The diagrams will show how the electrical units in the equipment are connected and the location of fuses and automatic switches.

Many diagrams show a color code for each wire in a particular circuit. The headlight circuit, for example, may have wires marked BK and G which would mean black wire cable and green wire cable. Wires in another circuit could be marked WR to indicate a white wire with a red tracer. Whether the diagram shows these designations or not, you will find wires of the



CODE	COLOR	CODE	COLOR	CODE	COLOR
BW	BROWN - WHITE TRACER	BLW	BLUE - WHITE TRACER	GW	GREEN - WHITE TRACER
BK	BLACK	BLR	BLUE - RED TRACER	Y	YELLOW
BKG	BLACK - GREEN TRACER	R	RED	YBK	YELLOW - BLACK TRACER
BKBL	BLACK - BLUE - TRACER	RW	RED - WHITE TRACER	YG	YELLOW - GREEN TRACER
BKY	BLACK - YELLOW TRACER	RY	RED - YELLOW TRACER	YR	YELLOW - RED TRACER
BKR	BLACK - RED TRACER	RBK	RED - BLACK TRACER	W	WHITE
BKW	BLACK - WHITE TRACER	G	GREEN	WR	WHITE - RED TRACER
BL	BLUE	GBK	GREEN - BLACK TRACER		
		B	BROWN		

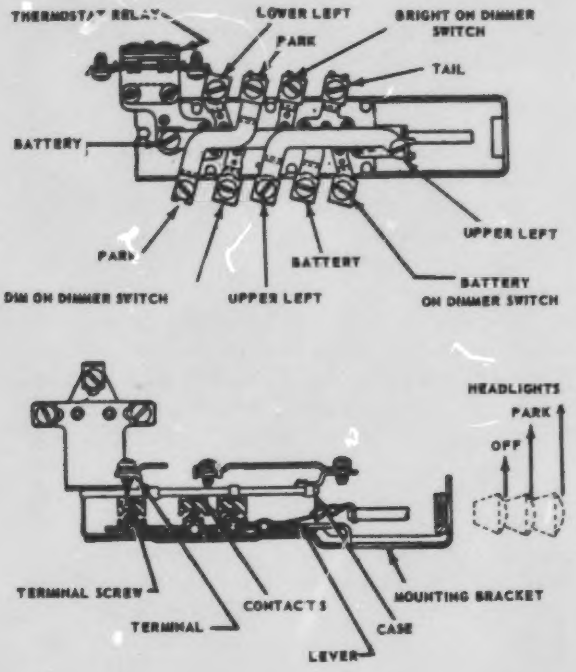
FUSE DATA

CIRCUIT	NO. USED	CAPACITY
LIGHTING	1	20 AMP.
ACCESSORY	1	30 AMP.
CLOCK	1	2 AMP.
DIRECTION INDICATOR	1	10 AMP.

INDICATING FUSE
INDICATING WIRE CONNECTOR
HEADLAMP
BONNET SIDE PANEL LAMP
IGNITION COIL
BKR
IGNITION SWITCH
STARTER BUTTON
6 CYLINDER DISTRIBUTOR
1
2
3
4
5
6
OIL PRESSURE ELEMENT
CLOCK FUSE
CLOCK
CLOCK PANEL LIGHTS
GENERATOR SIGNAL
OIL SIGNAL
WATER TEMPERATURE GAUGE
GAS GAUGE
WATER TEMPERATURE ELEMENT
GASOLINE GAUGE TANK UNIT
IGNITION LOCK LIGHT
RHEOSTAT SWITCH
GENERATOR
STARTER
HORN BUTTON
INST PANEL CIGAR LIGHTER
SPEEDOMETER PANEL LIGHTS
TAIL AND STOP LAMP
TAIL LAMP JUNCTION BLOCK
REAR LICENSE LAMP
BATTERY
VOLTAGE REGULATOR
FUSE BLOCK
HEAD LAMP JUNCTION BLOCK
VIBRATION HORN
HEAD LAMP FOOT SWITCH
HEADLAMP BEAM INDICATORS
LIGHTING SWITCH
STOP LAMP SWITCH
BK
BKY
BKG
BKW
BKBL
BLR
GA
YBK
YG
RY
R
G
W
WR
Y

81.144

Figure 7-35.—Wiring diagram of passenger car showing standard equipment and color code for wires.



81.145

Figure 7-36.–Side and top view of a typical lighting switch.

same color connecting units in an individual circuit. That is true, of course, if the original wire has not been replaced or improperly connected. Keeping the electrical system and its components free of dirt and oil will reduce the number of failures and make it easier to locate troubles in the circuits.

ONE- AND TWO-WIRE CIRCUITS

Tracing wiring circuits, particularly those connecting lights or warning and signal devices, is no simple job. By studying the diagram in figure 7-35, you will see that the branch circuits making up the individual systems have one wire to conduct electricity from the battery to the unit requiring it, and ground connections at the battery and the unit to complete the circuit. These are called one-wire circuits or branches of a GROUND RETURN SYSTEM. The all-metal construction of automotive equipment makes it possible to use this system.

In automotive electrical systems with branch circuits that lead to all parts of the equipment, the ground return system saves installation time and eliminates the need for an additional wire from each electrical unit to complete the circuit.

A so-called TWO-WIRE SYSTEM requires two wires to complete the electrical circuit–one wire from the source of electrical energy to the unit it will operate, and another wire to complete the circuit from the unit back to the source of electric power.

Two-wire circuits provide positive connections for lights and electric brakes on some trailers. The coupling between the trailer and the equipment, although made of metal and a conductor of electricity, has to be jointed to move freely. The rather loose joint or coupling does not provide the positive and continuous connection needed to use a ground return system between the two vehicles. The two-wire system is commonly used on equipment subject to frequent or heavy vibrations. Tracked equipment, off-the-road vehicles (tactical) and many types of construction equipment are wired in this manner.

When tracing a circuit to locate problems, start from the source of power. This will often save time while insuring that the complete circuit is in good condition. When the wiring is wrapped in a protective covering such as tape or other material, it may become necessary to remove the covering to locate the problem. Should this become necessary, make sure you replace the tape or other covering to prevent fraying of the wires from vibration or rubbing against moving parts, and to prevent damage to the wires from exhaust heat.

The operation and maintenance manual, besides furnishing wiring diagrams, will give information on the maintenance and repair of electrical units. Read these manuals–the information you will get from them, plus the basic principles you can find in *Basic Electricity*, NAVPERS 10086-B, will make your job easier.

WIRING COLOR CODE

Wiring color codes are used by manufacturers to assist their service personnel in identifying the wires used in the many circuits and making repairs in a minimum of time. No color code is common to all manufacturers. For this reason, the manufacturer's maintenance manual is a must for speedy troubleshooting and repairs.

The wiring found on tactical equipment (M-series vehicles) has no color coding. All the wire used on these vehicles is black. Small metal tags, stamped with numbers, are used to identify the wiring illustrated by diagrams in the technical manuals provided with the equipment. These tags are securely fastened near each end of individual wires.

WIRING DIAGRAMS

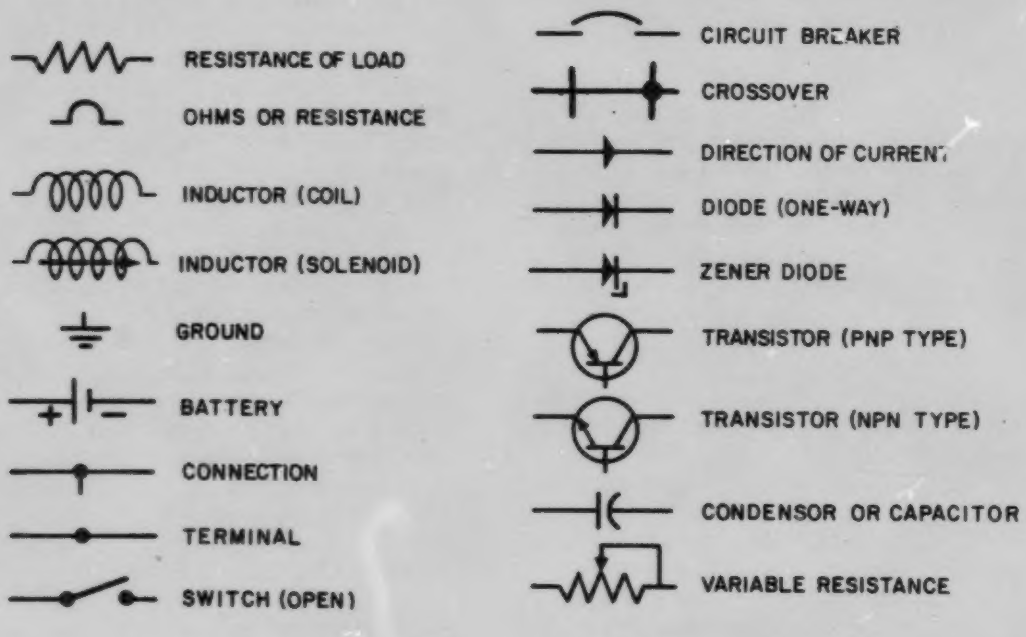
Often you will find ELECTRICAL SYMBOLS used in wiring diagrams to simulate the individual components. Figure 7-37 illustrates some of the symbols you may encounter when tracing individual circuits in a wiring diagram.

Diagrams seldom show the routing of the wires within the electrical system of the vehicle. Most only show the general location of the components in relation to each other and identify the wires that connect them in the system.

PREVENTIVE MAINTENANCE

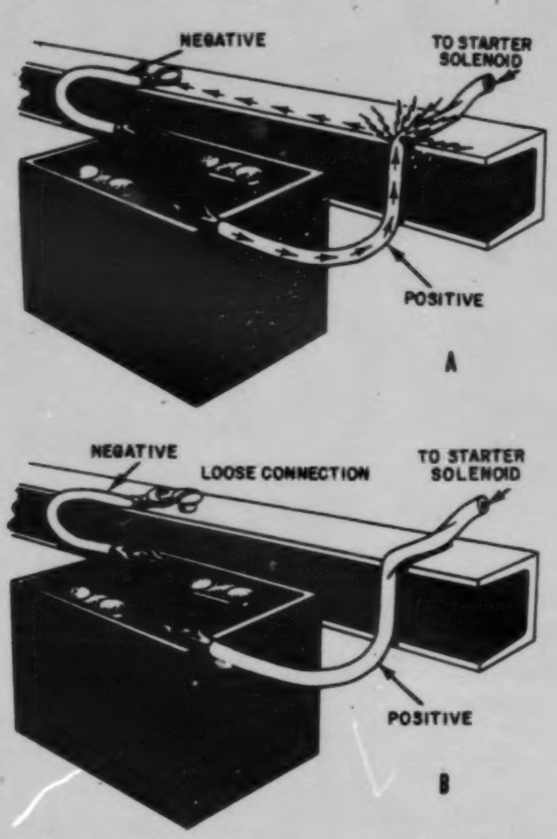
The wiring diagrams tell only what circuits and units are in the equipment—not where they are placed—nor how they are actually connected. Electricity will flow in the path of least resistance, and if the resistance is too great, will not flow at all. Keep these facts in mind; they will answer many of your problems in the maintenance of lighting systems. Notice the method of grounding the battery to the frame.

The short circuit illustrated in view A, figure 7-38 shows what happens when the wire insulation wears through. Current from the battery will go directly to ground and result in a dead battery. This same condition is common in circuits found on all types of equipment. Usually the light or other accessory will not function properly or will fail to work at all


RESISTANCE OF LOAD
OHMS OR RESISTANCE
INDUCTOR (COIL)
INDUCTOR (SOLENOID)
GROUND
BATTERY
CONNECTION
TERMINAL
SWITCH (OPEN)
CIRCUIT BREAKER
CROSSOVER
DIRECTION OF CURRENT
DIODE (ONE-WAY)
ZENER DIODE
TRANSISTOR (PNP TYPE)
TRANSISTOR (NPN TYPE)
CONDENSOR OR CAPACITOR
VARIABLE RESISTANCE

81.530

Figure 7-37.—Wiring diagram symbols.



81.125

Figure 7-38.—(A) Short circuit; (B) Open circuit.

because a fuse or circuit breaker has opened the circuit. As mentioned previously, the fault is not the safety device, and the real problem must be corrected before the circuit will function normally. Short circuits of this kind can result in fire from overheated wires, or from sparks resulting from the bare wire making and breaking contact with the car frame.

The open circuit caused by a loose connection (as shown in view B, fig. 7-38) is common in electrical systems. The expression OPEN CIRCUIT is used not only when the wire connections are actually separated as in a switch, but also when the resistance in the wiring circuit is so great that no current can flow between the battery and the unit it operates. An example is rust and corrosion that forms or accumulates at a joint or wire terminal that actually feels tight. This condition is very often found at the battery terminals between the terminal and cable clamp.

WIRING HARNESS

Wiring harnesses serve two purposes. They prevent chafing and loosening of terminals and connections caused by vibration and road shock while keeping the wires in a neat condition away from moving parts of the vehicle. A wiring harness contains a number of wires insulated by tape or a nonmetallic braided covering. As shown in figure 7-39, each wire included in a wiring harness can be used for a separate circuit.

WIRE SUPPORT AND PROTECTION

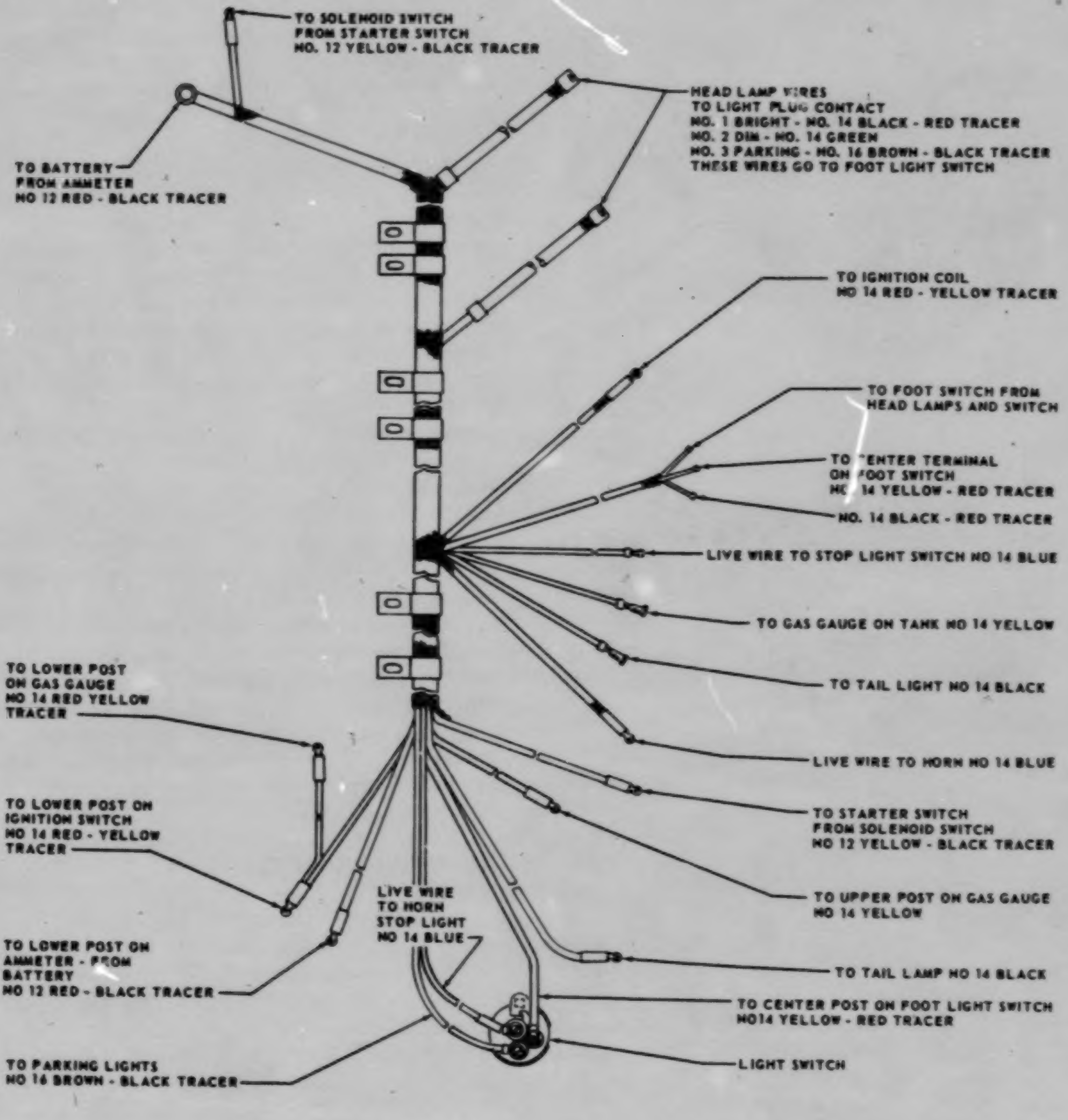
Wires in the electrical systems should be supported by clamps or fastened by tape at various points about the vehicle. When you install a new wire, be sure to keep it away from the hot engine parts that would scorch or burn the insulation. Wires passing through holes in metal members of the frame or body should be protected by rubber grommets or several turns of friction tape to prevent chafing or cutting on sharp edges.

GROUND CONNECTIONS

Be sure that the ground return connections made to the chassis frame or engine are clean and tight. Where the engine or body is mounted on rubber or other insulating material, there should be a flexible metal connection. A half turn on the fastening screw or bolt will prevent the formation of a film of rust or corrosion. Even if this screw or bolt is tight, rust or corrosion at the ground connection will prevent current from flowing in the circuit.

FIELD AND SHOP REPAIR

Dependable operation of the electrical systems is your responsibility. Usually you will make limited repairs in the field and do your overhaul in the shop. In the shop the electrical


TO SOLENOID SWITCH
FROM STARTER SWITCH
NO. 12 YELLOW - BLACK TRACER
HEAD LAMP WIRES
TO LIGHT PLUG CONTACT
NO. 1 BRIGHT - NO. 14 BLACK - RED TRACER
NO. 2 DIM - NO. 14 GREEN
NO. 3 PARKING - NO. 16 BROWN - BLACK TRACER
THESE WIRES GO TO FOOT LIGHT SWITCH
TO BATTERY
FROM AMMETER
NO 12 RED - BLACK TRACER
TO IGNITION COIL
NO 14 RED - YELLOW TRACER
TO FOOT SWITCH FROM
HEAD LAMPS AND SWITCH
TO CENTER TERMINAL
ON FOOT SWITCH
NO. 14 YELLOW - RED TRACER
NO. 14 BLACK - RED TRACER
LIVE WIRE TO STOP LIGHT SWITCH NO 14 BLUE
TO GAS GAUGE ON TANK NO 14 YELLOW
TO TAIL LIGHT NO 14 BLACK
TO LOWER POST
ON GAS GAUGE
NO 14 RED YELLOW
TRACER
LIVE WIRE TO HORN NO 14 BLUE
TO STARTER SWITCH
FROM SOLENOID SWITCH
NO 12 YELLOW - BLACK TRACER
TO LOWER POST ON
IGNITION SWITCH
NO 14 RED - YELLOW
TRACER
TO UPPER POST ON GAS GAUGE
NO 14 YELLOW
LIVE WIRE
TO HORN
STOP LIGHT
NO 14 BLUE
TO LOWER POST ON
AMMETER - FROM
BATTERY
NO 12 RED - BLACK TRACER
TO TAIL LAMP NO 14 BLACK
TO CENTER POST ON FOOT LIGHT SWITCH
NO14 YELLOW - RED TRACER
LIGHT SWITCH
TO PARKING LIGHTS
NO 16 BROWN - BLACK TRACER

81.147

Figure 7-39.—A typical wiring harness.

units are disassembled when major repairs require special tools and equipment.

But, if you find electrical troubles in the field that you do understand and feel confident that you can repair, do not make just a temporary fix; do it right the first time. You will save time in the end and gain the confidence of your supervisor as well as the operator. Should there be some question about other troubles you will surely run into, check your operation and repair manual and report what you have found to the chief in charge of the shop.

SOLDERING

Soldering operations are a vital part of electrical maintenance procedures. Soldering is a manual skill which can and must be learned by all personnel who work in the field of electricity. Practice is required to develop proficiency in the techniques of soldering; however, practice serves no useful purpose unless it is founded on a thorough understanding of basic principles. This discussion is devoted to providing information regarding some important aspects of soldering operations.

Cleanliness is necessary for efficient, effective soldering. Solder will not adhere to dirty, greasy, or oxidized surfaces. Heated metals tend to oxidize rapidly, and the oxide must be removed prior to soldering. Oxides, scale, and dirt can be removed by mechanical means (such as scraping or cutting with an abrasive) or by chemical means. Grease or oil films can be removed by a suitable solvent. Cleaning should be accomplished immediately prior to the actual soldering operation.

Items to be soldered should normally be tinned before making mechanical connection. When the surface has been properly cleaned, a thin, even coating of flux may be placed over the surface to be tinned to prevent oxidation while the part is being heated to soldering temperature. Rosin core solder is usually preferred in electrical work, but a separate rosin flux may be used when tinning wires in cable fabrication. Tinning is the coating of the material to be soldered with a light coat of solder.

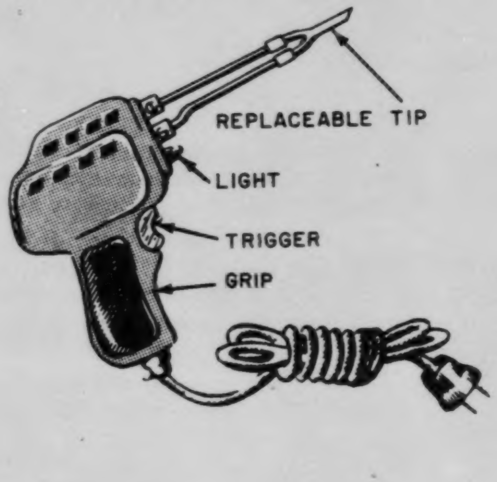
The tinning on a wire should extend only far enough to take advantage of the depth of the terminal or receptacle. Tinning or solder on wires subject to flexing causes stiffness, and may result in breakage.

The tinned surfaces to be joined should be shaped and fitted, then mechanically joined to make good mechanical and electrical contact. They must be held still with no relative movement of the parts. Any motion between parts will likely result in a poor solder connection.

The induction type soldering iron (most often referred to as soldering gun) is shown in figure 7-40. It contains a stepdown transformer in its body. The transformer secondary output current flows through the tip, causing it to heat. The tip heats only when the trigger is depressed, and then very rapidly. This type of iron affords easy access to cramped quarters, because of its small tip. It usually has a small light which is focused on the tip working area. The soldering tip is replaceable.

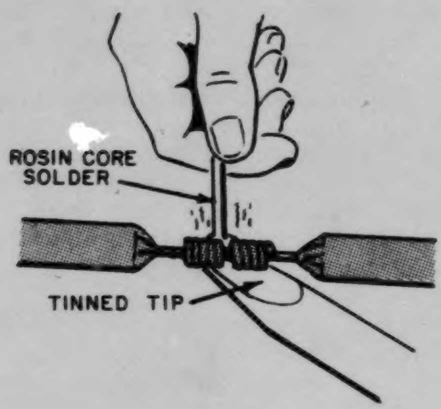
Tinning of the tip is always desirable unless it has already been done. The gun or iron should always be kept tinned in order to permit proper heat transfer to the work to be soldered.

To solder an electrical connection, the tinned portion of the iron tip is held flat against the connection, as shown in figure 7-41. Touch solder to the connection until the entire connection is covered with molten solder. Remove the solder, but continue to apply heat for a moment; then remove the iron and allow the solder to harden. The solder should always be melted by the heated wire and not by the iron. Melting the solder onto the iron and then transferring it to the connection often results in a cold solder joint, with the solder not actually holding to the wire or connection. Only enough solder to fill all crevices and spaces in the joint should be used.



81.453

Figure 7-40.—Soldering gun.



81.454

Figure 7-41.—Soldering a splice.

Both the solder and the material to be soldered must be heated to a temperature which allows the solder to flow. If either is heated inadequately, cold solder joints result. Such joints do not provide either the physical strength or the electrical conductivity required. Appreciably exceeding the flow point temperature, however, is likely to cause damage to the parts being soldered. Various types of solder flow at different temperatures. In soldering operations, it is necessary to select a solder that will flow at a temperature low enough to avoid damage to the part being soldered, or to any other part or material in the immediate vicinity.

The duration of high heat conditions is almost as important as the temperature. Insulation and many other materials in electrical equipment are susceptible to damage from heat. They are damaged if exposed to excessively high temperatures, or deteriorate if exposed to less drastically elevated temperatures for prolonged periods. The time and temperature limitations depend on many factors—the kind and amount of metal involved, the degree of cleanliness, the ability of the material to withstand heat, and the heat transfer and dissipation characteristics of the surroundings.

The three grades of solder generally used for electrical work are 40-60, 50-50, and 60-40 solder. The first figure is the percentage of tin, while the other is the percentage of lead. Solder with a high tin content melts at lower temperatures, flows more readily, cools faster, and is easier to work with than solder with a low tin content.

In addition to the solder, there must be flux to remove any oxide film on the metals being joined, otherwise they cannot fuse. The flux enables the molten solder to wet the metals so the solder can stick. The two types of flux are acid flux and rosin flux. Acid flux is more active in cleaning metals but is corrosive. Rosin is always used for the light soldering work in making wire connections. Generally, the rosin in the hollow core of solder intended for electrical work, so that a separate flux is unnecessary. It should be noted, though, that the flux is not a substitute for cleaning the metals to be soldered. The metal must be shiny clean for the solder to stick.

SOLDERLESS CONNECTORS

Splices and terminal lugs which do not require solder are more widely used than those which do require solder. Solderless connectors are attached to their conductors by means of several different devices, but the principle of each is essentially the same. They are all squeezed (crimped) tightly onto their conductors. They afford adequate electrical contact, plus great mechanical strength. In addition, solderless connectors are easier to mount correctly because they are free from the most common problems of solder connector mounting; namely, cold solder joints, burned insulation, and so forth.

Solderless connectors are made in a great variety of sizes and shapes, and for many different purposes.

The crimp-on splice (fig. 7-42) is the simplest of the splices. The type shown is preinsulated, though uninsulated types are manufactured. These splices are mounted with a special plier-like hand-crimping tool designed for that purpose. The stripped conductor tips are inserted in the splice, which is then squeezed tightly closed. The insulting sleeve grips the outer insulated conductor, and the metallic internal splice grips the bare conductor strands.

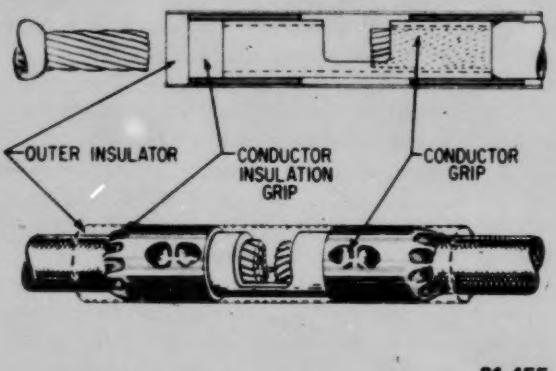


Figure 7-42.—Crimp-on splice.

TAPE

Putting rubber tape over the splice means that the insulation is being restored to a great degree. It is also necessary to restore the protective covering. FRICTION TAPE is used for this purpose; it also affords a minor degree of electrical insulation.

Friction tape is a cotton cloth that has been treated with a sticky rubber compound. It comes in rolls similar to rubber tape except that no paper or cloth separator is used. Friction tape is applied like rubber tape; however, it does not stretch.

The friction tape should be started slightly back on the original braid covering. Wind the tape so that each turn overlaps the one before it; and extend the tape over onto the braid covering at the other end of the splice. From this point a second layer is wound back along the splice until the original starting point is reached. Cutting the tape and firmly pressing down the end complete the job. When proper care is taken, the splice can take as much abuse as the rest of the wire.

PLASTIC ELECTRICAL TAPE has come into wide use in recent years. It has certain advantages over rubber and friction tape. For example, it will withstand higher voltages for a given thickness. Single thin layers of certain commercially available plastic tape will stand several thousand volts without breaking down. However, to provide an extra margin of safety, several layers are usually wound over the splice. Because the tape is very thin, the extra layers add only a very small amount of bulk, but at the same time the added protection, normally furnished by friction tape, is provided by the additional layers of plastic tape. In the choice of plastic tape, the factor of expense must be balanced against the other factors involved.

Plastic electric tape normally has a certain amount of stretch so that it easily conforms to the contour of the splice without adding unnecessary bulk. The lack of bulkiness is especially important in some junction boxes where space is at a premium.

ELECTRICAL FIRES

Electrical fires are extremely dangerous, because of the danger of electrical shock. In automotive vehicles the grease and oil drip onto and stick to the engine block and other accessories, adding to the fire hazard.

A short circuit in an automotive vehicle electrical system will not always cause a fire, but a fire can easily result from such a defect. By frequently inspecting, repairing, and maintaining the electrical system in the vehicle, you help prevent fires and electrical failures. Not only must you know how to prevent fires, you must also know what to do in case a fire gets started. Remember? NEVER USE WATER ON ELECTRICAL OR PETROLEUM FIRES.

The correct extinguishing agent for electrical fires is CO_2.

ACCESSORY CIRCUITS

Accessory circuits are provided on Navy vehicles for convenience and safety. Accessories, such as turn signals, windshield wipers and washers, and heaters, make operation of the vehicle convenient for the operator. You will find that some accessories formerly used only in the passenger cars are presently being used on military trucks and heavy equipment.

One of the more important accessories that provides a safety feature for the operator is the turn signals. Turn signals warn drivers of other vehicles that a turn is about to be made and not to follow too closely, or to use caution when approaching. This circuit is simply another lighting circuit that operates on an intermittent basis.

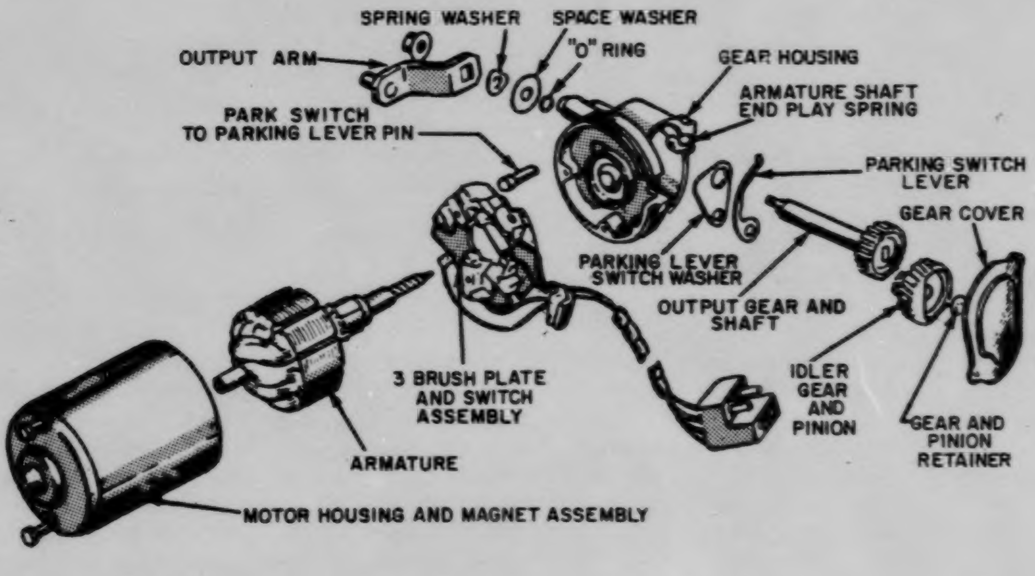
Turn signals are operated by a circuit breaker commonly called a "flasher." This flasher should emit a clicking noise when the directional control switch, located on the steering column, is placed in the right- or left-turn position.

Maintenance of turn signals is normally limited to replacement of a burnt out bulb or faulty flasher. The directional control switch may become defective after extended use and require replacement. Directional controls installed by the manufacturer are located inside the steering column. Access is gained by removal of the steering wheel. On military vehicles, the control switch is clamped to the steering column.

Another safety item that works in conjunction with the turn signals is the "Emergency Flasher." The Emergency Flasher causes all the turn signal lights to blink simultaneously informing any approaching vehicle that you are stopped. The switch controlling the Emergency Flasher is usually a part of the turn-signal switch and operates from current supplied from a separate wire. This allows the Emergency Flasher to operate even though the turn indicators are faulty.

Electric windshield wipers operate from a circuit which contains a switch, motor and linkage connected to the wiper arms. Wiper motors operate on one, two, or three speeds. The motor (fig. 7-43) has a worm gear on the armature shaft that drives one or two gears which, in turn, operate the linkage to the wiper arms. The motor is a small, shunt wound, d-c motor. Resistors are placed in the control circuit from the switch to reduce the current and provide different operating speeds.

Accessory motors are all basically the same, although size, location and method of drive found on the armature shaft may vary. These motors are normally replaced when they fail to operate. Usually, operating problems are not in the motor but in the control circuit from the switch.


SPRING WASHER
SPACE WASHER
OUTPUT ARM
"O" RING
GEAR HOUSING
ARMATURE SHAFT END PLAY SPRING
PARK SWITCH TO PARKING LEVER PIN
PARKING SWITCH LEVER
GEAR COVER
PARKING LEVER SWITCH WASHER
OUTPUT GEAR AND SHAFT
3 BRUSH PLATE AND SWITCH ASSEMBLY
IDLER GEAR AND PINION
GEAR AND PINION RETAINER
ARMATURE
MOTOR HOUSING AND MAGNET ASSEMBLY

81.531

Figure 7-43.—Windshield wiper motor.

CHAPTER 8

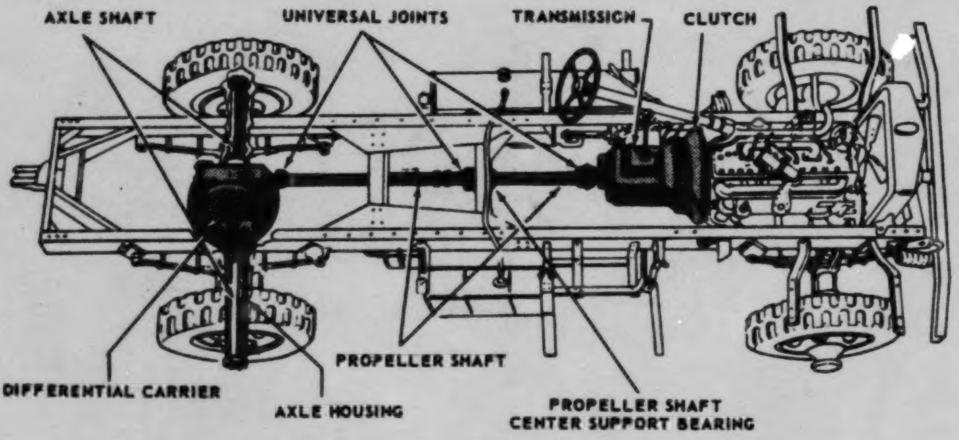
AUTOMOTIVE POWER TRAINS

In a vehicle, the mechanism that transmits the power developed by the engine to the wheels and/or tracks and accessory equipment is called the POWER TRAIN. In a simple application, such as a stationary engine-powered hoist, a set of gears or a chain and sprocket could perform this task. However, automotive and construction vehicles are not designed for such simple operating conditions. They are designed to provide pulling power, to move at high speeds, to travel in reverse as well as forward, and to operate on rough terrain as well as smooth roads. To meet these varying conditions, vehicle power trains are equipped with a variety of components.

Automobiles and light trucks driven by the two rear wheels have a power train consisting of a clutch, transmission, propeller shaft, differential, and driving axles (fig. 8-1).

In all-wheel drive vehicles, additional components are needed to transmit power to the front wheels. This is done with the use of a transfer case, additional propeller shafts, differential units, and driving axles.

Power trains you will encounter may include all or a combination of the components mentioned above. Variations in design and application make it impossible to cover all types in this manual. While most of the examples and figures used in this chapter involve automotive vehicles, it is well to remember that similar power train units are used in construction and material/weight handling equipment. A propeller shaft or a clutch, for example, may be constructed differently to conform to the



81.174

Figure 8-1.—Power train.

requirements of a particular item of equipment, but its purpose and principle of operation are the same.

This chapter discusses the basic types of automotive power train components you will encounter as a Construction Mechanic. When performing maintenance or repairs in the field or shop on components you are unfamiliar with, consult the operation and maintenance manuals provided with the equipment.

THE CLUTCH

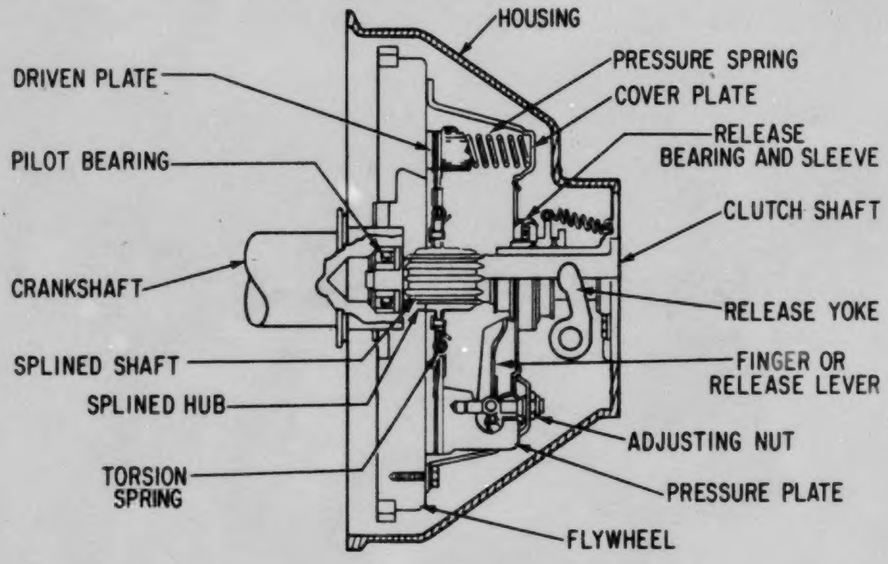
The clutch is the component in the power train that connects the engine crankshaft to, or disconnects it from, the operating control unit in stationary equipment, or the transmission (and thus the remainder of the power train) in automotive, construction, and materials/weight handling equipment.

With few exceptions, the clutches common to SEABEE equipment are the single, double, and multiple disk types. The clutch you will encounter most often is the SINGLE DISK type shown in figure 8-2. The DOUBLE DISK clutch (fig. 8-3) is substantially the same as the single disk clutch, except that another driven disk and an intermediate driving plate are added. This clutch is used in heavy-duty vehicles and construction equipment. The MULTIPLE DISK clutch (not shown) is used primarily as a steering clutch in tracklaying equipment. The operating principles, component functions, and maintenance requirements are essentially the same for each of the three clutches mentioned. This being the case, the single disk clutch will be used to acquaint you with the fundamentals of clutch operation.

CLUTCH OPERATION

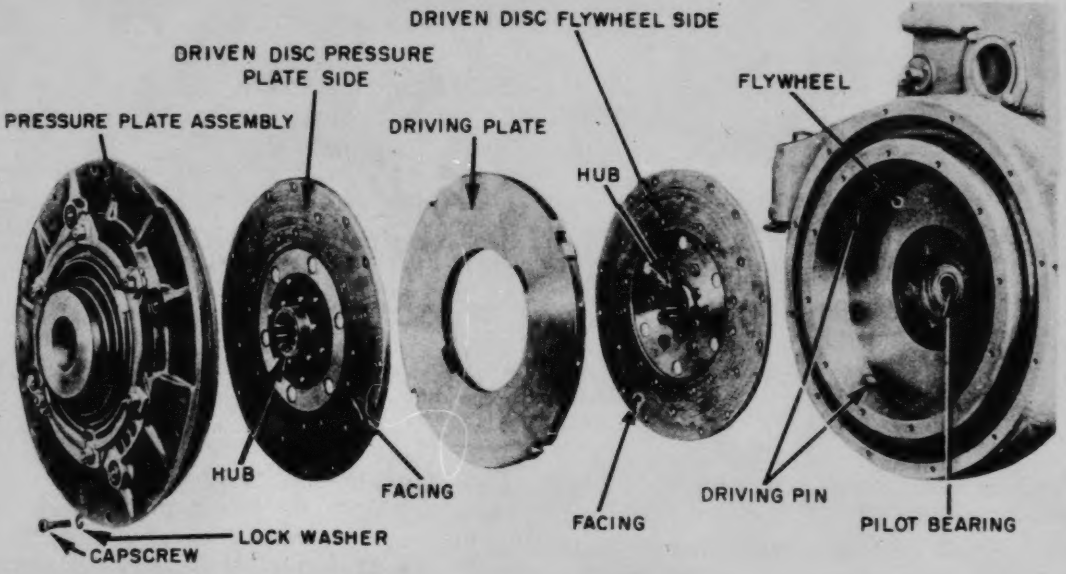
The single disk clutch (fig. 8-2) is used primarily in the power trains of passenger cars and light trucks. The major components of the single disk clutch are the driving members (flywheel and pressure plate), the driven member (disk), and the release mechanism.

The pressure plate assembly shown in figure 8-4 is secured to the engine flywheel. In


HOUSING
PRESSURE SPRING
DRIVEN PLATE
COVER PLATE
RELEASE BEARING AND SLEEVE
PILOT BEARING
CLUTCH SHAFT
CRANKSHAFT
RELEASE YOKE
SPLINED SHAFT
FINGER OR RELEASE LEVER
SPLINED HUB
ADJUSTING NUT
TORSION SPRING
PRESSURE PLATE
FLYWHEEL

81.532

Figure 8-2.—Single disk clutch.


DRIVEN DISC FLYWHEEL SIDE
DRIVEN DISC PRESSURE PLATE SIDE
PRESSURE PLATE ASSEMBLY
DRIVING PLATE
FLYWHEEL
HUB
HUB
FACING
FACING
DRIVING PIN
PILOT BEARING
LOCK WASHER
CAPSCREW

81.179

Figure 8-3.–Double disk clutch, exploded view.

operation the pressure plate is gradually brought in or out of contact with the disk by means of the release mechanism. When the clutch is fully engaged (fig. 8-5), the driven disk, which is splined to the clutch shaft and faced on both sides with friction material, is firmly clamped between the driving members by spring pressure. In this position, the driven disk rotates the clutch shaft and transfers the engine power to the transmission and thus the remainder of the power train. When the clutch pedal is depressed (fig. 8-5), linkage causes the release levers to overcome the spring tension and retract the pressure plate into the pressure plate assembly cover. In this position, the driven disk centers itself on the splines, between the driving

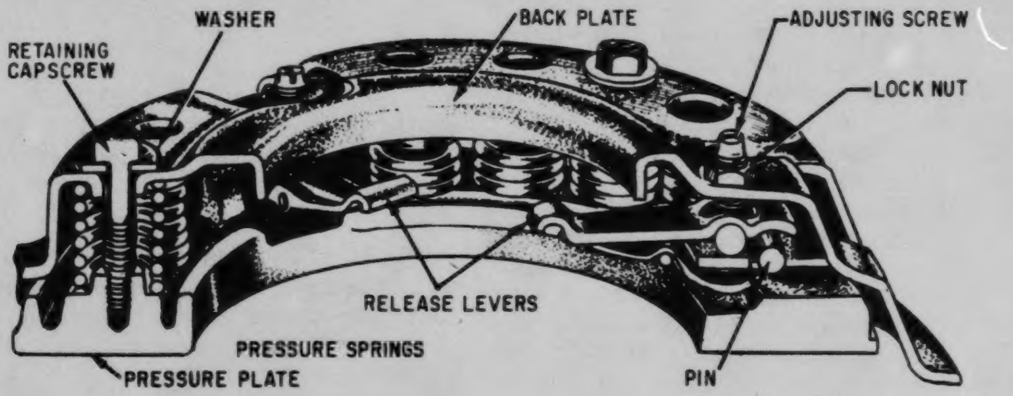

WASHER
RETAINING CAPSCREW
BACK PLATE
ADJUSTING SCREW
LOCK NUT
RELEASE LEVERS
PRESSURE SPRINGS
PRESSURE PLATE
PIN

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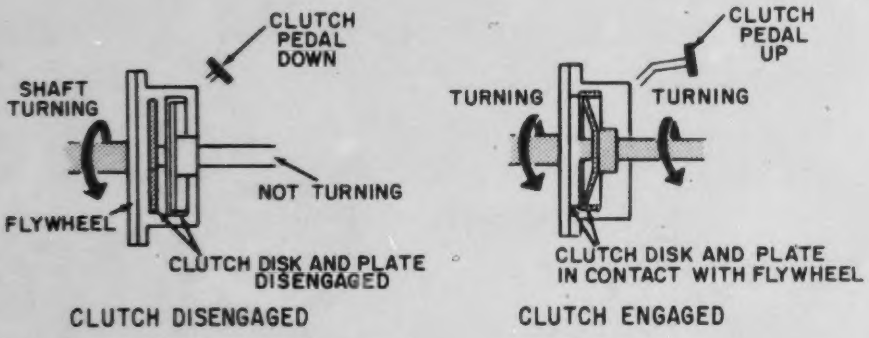
Figure 8-4.–Pressure plate assembly.



81.534

Figure 8-5.—Clutch operation.

members, and no power is transferred to the remainder of the power train.

The release mechanism common to most single disk clutches consists of a release bearing and sleeve, and a release yoke similar to the one illustrated in figure 8-2. The release sleeve slides on the transmission front mainshaft bearing retainer as the clutch pedal is depressed. The yoke moves the sleeve forward and the release bearing contacts the release levers of the pressure plate assembly. Further motion causes the pressure springs to compress, retracting the pressure plate and releasing the disk.

In most clutches, mechanical linkage (fig. 8-6) between the clutch release yoke lever and clutch pedal provides the operator with a means to actuate the clutch. On many late model vehicles, and on some of the larger units which require great pressure to release the clutch, a hydraulic release system (fig. 8-7) is used. A master cylinder similar to the brake master cylinder is attached to the clutch pedal. A cylinder, similar to a single-acting brake wheel cylinder, is connected to the master cylinder by flexible pressure hose or metal tubing. The slave cylinder is connected to the clutch release yoke lever. Movement of the clutch pedal actuates the clutch master cylinder. This movement is transferred by hydraulic pressure to the slave cylinder, which in turn actuates the clutch release yoke lever.

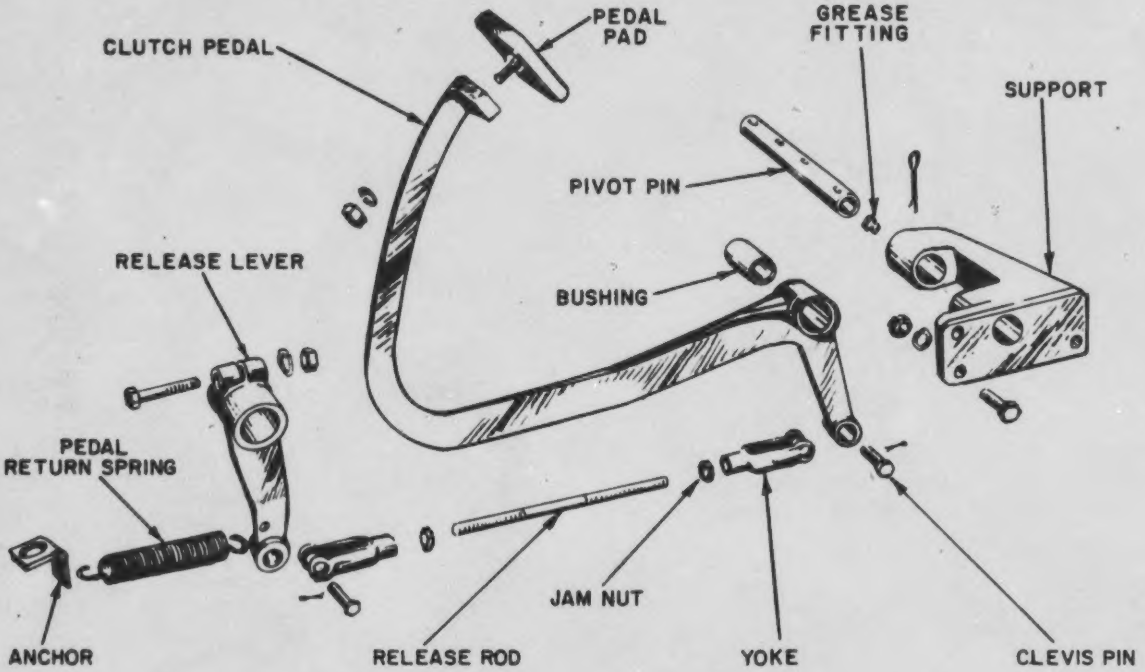
A spring is used to keep the release bearing and levers separated when the clutch is engaged. This prevents the bearing from constantly spinning, while the engine is running, and wearing out the release levers and/or causing rapid bearing failure. Modern clutch linkages provide a method of connecting the release sleeve and yoke so that the bearing is retracted by the clutch pedal return spring acting on the clutch linkage. With this arrangement, the bearing contacts the release levers only when the clutch pedal is partially depressed. Resting a foot on the clutch pedal while driving or improper adjustment can cause rapid failure of the bearing.

CLUTCH PEDAL ADJUSTMENT

Clutch pedal adjustments are made to compensate for wear of the clutch facings and linkage between the clutch pedal and the clutch release lever. Most light- and medium-duty clutch linkages provide for adjustment to change the length of the release rod illustrated in figure 8-6.

As wear of the clutch disk occurs, the clutch pedal free travel becomes less. If allowed to wear excessively before adjusting, you may find that the release bearing is constantly in contact with the release levers and the bearing will fail earlier than normal.

Depending on the arrangement of the linkage, the length of the release rod is either



81.535

Figure 8-6.—Clutch pedal and linkage.

shortened or lengthened to compensate for normal clutch wear. The hydraulically operated clutch illustrated in figure 8-7 is adjusted by changing the length of the slave cylinder push rod. When making a clutch adjustment, refer to the manufacturer's service manual for the correct method of adjustment and clearance. If no manuals are availalbe, an adjustment that allows 1 1/2 inches of clutch pedal free travel will allow adequate clutch operation until the vehicle reaches the shop and manuals are available.

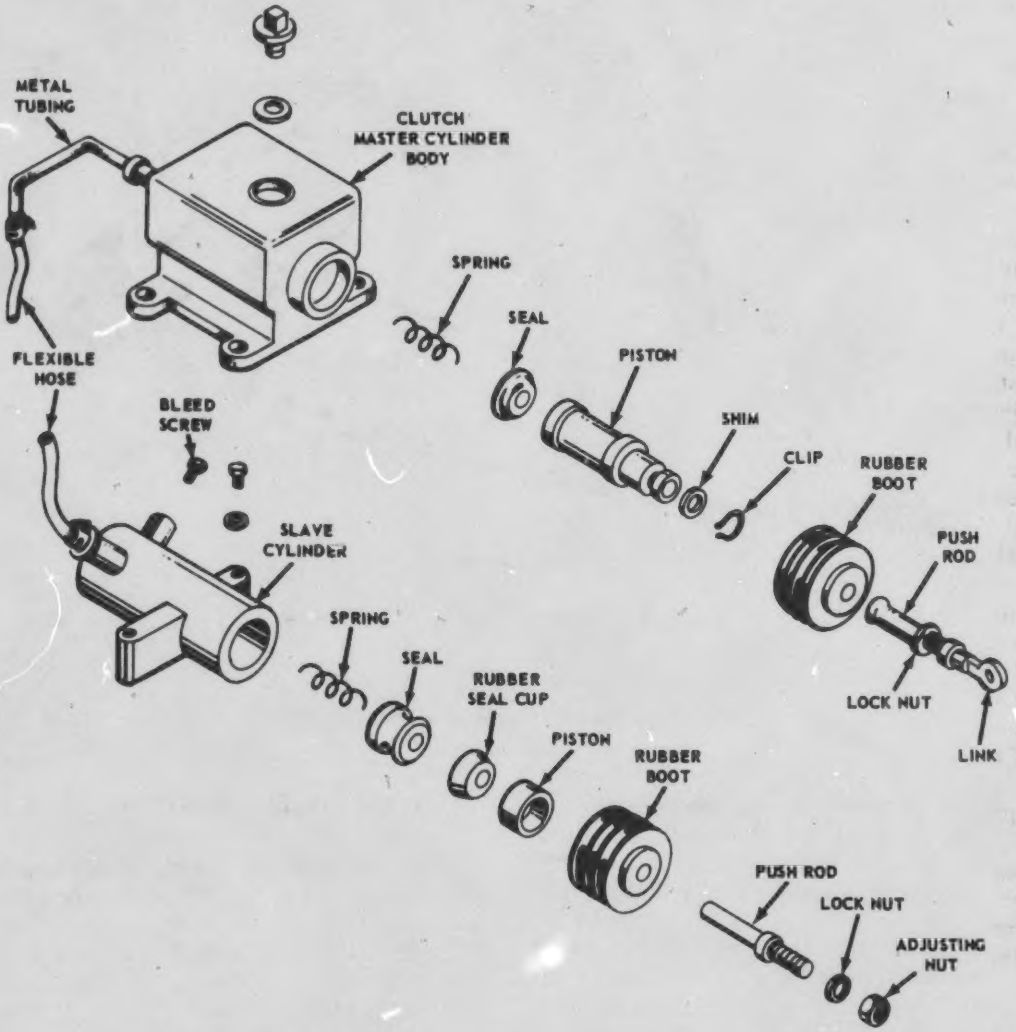
Double and multiple disk clutches often have a screw type of internal adjustment ring to compensate for wear. The adjustment ring is an integral part of the clutch assembly, and is used only when initially installing the clutch, or when the external adjustment–if so equipped–will not provide the correct clutch linkage free travel.

CLUTCH TROUBLESHOOTING

The information given in this section is general and can be applied to nearly every type of clutch that you are likely to encounter. You will probably have special problems for which the solution can be found only by referring to the manufacturer's manual.

Several types of clutch trouble may be encountered. Usually the trouble is fairly obvious. When the malfunction is explained on the Operator's Trouble Report, a quick personal check of the vehicle will generally enable you to correctly diagnose the trouble. It is your responsibility to see that the job is properly performed with a minimum of work. Clutch trouble generally falls into one of six categories:

1. Slipping
2. Chattering or grabbing when engaging


METAL TUBING
CLUTCH MASTER CYLINDER BODY
SPRING
SEAL
PISTON
SHIM
CLIP
RUBBER BOOT
PUSH ROD
FLEXIBLE HOSE
BLEED SCREW
SLAVE CYLINDER
SPRING
SEAL
RUBBER SEAL CUP
PISTON
RUBBER BOOT
LOCK NUT
LINK
PUSH ROD
LOCK NUT
ADJUSTING NUT

81.177

Figure 8-7.—Master cylinder, slave cylinder, and connections for standard hydraulic clutch.

3. Spinning or dragging when disengaging
4. Clutch noises
5. Clutch pedal pulsations
6. Rapid disk facing wear

Slipping

Slipping occurs when the driven disk fails to rotate at the same speed as the driving members when the clutch is fully engaged. This condition results whenever the clutch pressure plate fails to hold the disk tight against the face of the flywheel. If clutch slippage is severe, the engine speed will rise rapidly, on acceleration, while the vehicle gradually increases in speed. Slight but continuous slippage may go unnoticed until the clutch facings are ruined by excessive temperature caused by friction.

In many cases, clutch slippage is due to less than zero clearance between the clutch release levers and the release bearing. This results in slipping and early bearing failure. Normal wear of the facings causes the free travel of the clutch linkage to decrease, creating the need for an adjustment. Some clutch linkages are designed to allow only enough adjustment to compensate for the lining to wear close to the rivet heads. This prevents damage to the flywheel and pressure plate by the rivets wearing grooves in their smooth surfaces. When you are unable to obtain the correct free travel on clutches with this type of linkage, you must remove the clutch and install a new disk. Other linkages will allow for adjustment after the disk is worn out. When in doubt whether the disk is worn excessively, remove the inspection cover and measure the thickness of the clutch disk. If the disk is worn beyond the manufacturer's recommendations, a new disk must be installed.

Binding linkage or release levers may prevent the pressure plate from exerting its full pressure against the disk, allowing it to slip. Should the release sleeve stick on the extended portion of the transmission front bearing retainer, or the hub of the clutch disk stick on the splines of the clutch shaft, full engagement may not occur. These problems result in slippage.

Grease and oil on the disk will also cause slippage. When this occurs, the only sure remedy is to replace the clutch disk and thoroughly clean the clutch components before reassembly. The source of the lubricant leakage must also be stopped to prevent future occurrences.

Internal clutch problems such as weak springs and bent or improperly adjusted release levers will prevent the pressure plate from applying even pressure to the disk and allow it to slip only when heavy loads are applied to the clutch. Again, removal of the clutch is necessary to accomplish repairs.

Chattering or Grabbing When Engaged

There are several things that will cause a clutch to chatter or grab when it is being engaged. Loose spring shackles or U-bolts, loose transmission mounting, and worn engine mounts are among the items that must be checked. If the clutch linkage binds, it may release suddenly to throw the clutch into quick engagement, with a resulting heavy jerk. If all these items are checked and found to be in good condition, the trouble is inside the clutch itself. The clutch will have to be removed from the vehicle for repairs.

The trouble inside the clutch could be due to oil or grease on the disk facings or to glazed or loose facings. Binding of the friction disk hub on the clutch shaft could prevent smooth engagement; this condition will require cleaning up of the splines in the disk hub and on the clutch shaft. Broken parts in the clutch, such as broken disk facings, broken cushion springs in the disk, or a broken pressure plate, could cause poor clutch action or grabbing.

Spinning or Dragging When Disengaged

The clutch friction disk may spin briefly after the clutch is disengaged. In other words, it takes a moment for the friction disk to come to rest. This normal spinning should not be confused with a dragging clutch. When the clutch drags, the friction disk continues to rotate with and to rub against the flywheel or pressure plate.

When this condition exists, the first thing to check is the pedal-linkage adjustment. If there is excessive free travel of the clutch pedal even full movement of the pedal will fail to force the release bearing in far enough against the release levers to release the clutch fully. If adjustment of the linkage does not correct the trouble, the problem is in the clutch, which must be removed for repair. You will generally find a warped disk or pressure plate, or the facing on the disk may be loose. On the type of pressure plate assembly with adjustable release levers, improper adjustment of the levers could prevent full disengagement so that the clutch would drag. A friction disk hub that is binding on the clutch shaft can also cause the clutch to drag.

Clutch Noises

When an operator reports that a clutch is making noise, find out whether the noise is heard when the clutch is engaged or when it is disengaged. Clutch noises are usually most noticeable when the engine is idling and the clutch disengaged.

A disk hub that is loose on the clutch shaft will make a noise when the clutch is engaged. This would require replacement of the disk or clutch shaft or perhaps both, if both are worn excessively. Friction disk dampener springs that are weak or worn will also cause clutch noises. If the engine and transmission are not properly alined the disk hub will move back and forth on the clutch shaft. This will cause the splines of the disk hub and clutch shaft to wear; thus a noisy clutch will soon appear. Any time excessive wear is found on the splines of the disk hub and/or the clutch shaft, always check the transmission and engine alinement.

If clutch noises are noticeable when the clutch is disengaged, the trouble will likely be in the clutch release bearing. The bearing is probably either worn, binding, or has lost its lubricant. Most clutch release bearings are factory lubricated; however, on some of the larger trucks and on construction equipment the clutch release bearing does require lubrication. As a rule, when the release bearing starts making a noise, it must be replaced. If the release levers on the pressure plate assembly are not properly adjusted they could rub against the disk hub when the clutch is disengaged. If the pilot bearing in the crankshaft is worn or lacks lubricant, it will sometimes produce a high-pitched whine when the transmission is in gear, the clutch is disengaged, and the vehicle is standing still. Under these conditions, the clutch shaft, which is piloted in the bearing in the crankshaft, is stationary, but the crankshaft and bearing are turning.

Clutch Pedal Pulsation

A series of slight movements that can be felt on the clutch pedal or operating lever when the clutch is being disengaged is called clutch-pedal pulsation. These pulsations are noticeable when a slight pressure is applied to the clutch pedal. This is an indication of trouble that could result in serious damage if not corrected immediately. There are several conditions that can cause these pulsations. One possible cause is misalinement of the engine and transmission.

If the engine and transmission are not in line, detach the transmission and remove the clutch assembly. Check the clutch housing alinement with the engine and crankshaft. At the same time, the flywheel can be checked for wobble since a bent crankshaft flange, or a flywheel that is not seated on the crankshaft flange, will produce clutch pedal pulsations. If the flywheel does not seat on the crankshaft flange, remove the flywheel. After cleaning the flange and the flywheel, replace the flywheel, making sure a positive seat is obtained between the flywheel and crankshaft flange. If the flange is bent at the crankshaft, the crankshaft must be replaced.

Other causes of clutch pedal pulsations include uneven release-lever adjustments, warped pressure plate, or warped clutch disk. If either the pressure plate or clutch disk is warped, it should be replaced.

Rapid Disk Facing Wear

Rapid disk facing wear will be caused by any condition that permits slippage between the clutch disk facings and the flywheel or pressure plate. An operator may have the habit of "riding" the clutch; this practice can cause slippage. Frequent use of the clutch or slow releasing of the clutch after disengaging will increase clutch facing wear. The remedy here is to use the clutch properly and only when necessary. Broken or weak pressure springs within the plate assembly will cause slippage. The springs must be replaced to correct this problem. Improper clutch linkage adjustment or binding of the linkage may prevent full spring pressure from being applied to the clutch disk. Any condition that keeps less than full spring pressure from being applied to the clutch disk is apt to cause slipping.

CLUTCH LUBRICATION

Some clutches require lubrication at regular intervals. Check with the manufacturer's manual for instructions on the lubrication of the clutch release bearing. Overlubrication will cause the lubricant to get on the disk and cause slippage. The clutch pedal control shaft and linkages, however, are usually equipped with high pressure fittings. These fittings should be greased with chassis lubricant at each scheduled maintenance period to prevent binding or frozen linkage.

CLUTCH OVERHAUL

When adjustment or repair of the linkage fails to remedy problems with the clutch, the clutch must be removed for inspection. Any faulty parts should be discarded and replaced with new or rebuilt components. Machining of the flywheel or pressure plate to provide new contact surfaces is not recommended. This can be dangerous, as the flywheel or plate could explode at high rpm and cause damage to the vehicle as well as injury to any occupants inside the vehicle. If replacement parts are not readily available, a decision to use the old components should be based on the manufacturer's recommendations and the experience of your supervisor.

To remove the clutch, first remove the driveshaft and transmission using a transmission jack or a suitable substitute. Disconnect the clutch linkage and remove the release fork and release bearing. On some vehicles, the clutch linkage must be disconnected prior to removing the transmission. On others, it may be necessary to remove the clutch housing before the components can be removed from the flywheel. Access to light-duty clutches is normally provided through an inspection cover under the clutch and flywheel. With this design, the transmission is only moved far enough to the rear to withdraw the clutch shaft and allow removal of the release bearing and sleeve.

Before removing the pressure plate assembly from the flywheel, mark the cover and flywheel to insure proper balance if the old components are to be used. Next, if design allows, install retaining cap screws (see fig. 8-4) to relieve spring tension before removing the bolts that secure the pressure plate to the flywheel. These should be loosened one or two turns at a time working your way around the clutch cover to prevent distortion of the cover. When these bolts are taken out, the pressure plate and disk can be removed for inspection.

After cleaning the components of the clutch and flywheel, check the pressure plate cover visually. A straightedge or flat surface should be used to determine if the cover is distorted or warped. Its mounting holes should be in good condition and not show any out-of-roundness. The pressure plate should be free of cracks, scores, or any noticeable grooves in the wearing surface. The release levers should show very limited or no signs of wear from contact with the release bearing. In general, it is a good idea to replace the pressure plate assembly if any warpage or excessive wear is noted on any of the parts.

The flywheel should be inspected in the same manner as the pressure plate. If it shows signs of unusual wear, such as scoring or cracks, check with your supervisor to determine if it needs replacement. Using a scored or excessively cracked flywheel or pressure plate will shorten the life of a new disk and cause rework at an early date. While inspecting the flywheel, check the pilot bearing in the end of the crankshaft. Bushing type bearings should not show any signs of wear. Ball or roller type bearings should turn freely and show no signs of rough movement. It is usually a good idea to replace the pilot bearing when overhauling the clutch.

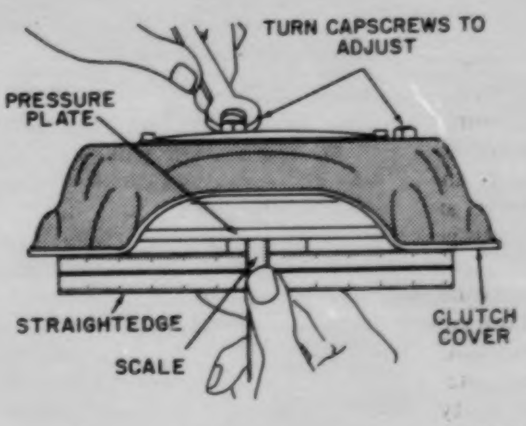
Inspect the disk for lining thickness, loose rivets, and worn or loose torsion springs. Check the splines in the hub for a "like new" condition. The clutch shaft splines should be inspected at this time by placing the disk on the clutch shaft and sliding it over the splines. If the disk is unusually tight or shows signs of binding on the splines, the splines must be cleaned with a file to remove any burrs. Any signs of unusual wear will require replacement of the clutch shaft or disk assembly. If a new disk is used, be sure that it moves on the shaft freely. If you replace the old lining on the disk, follow the manufacturer's recommended procedure. Rebuilding of the clutch components is seldom done in the maintenance shop or field.

If, during removal, oil or grease is found on the disk, the source of the lubricant must be found and corrective measures taken to prevent its reentry into the clutch housing.

One important thing that must be done prior to reassembly of the clutch is to determine if the pressure plate has provisions for adjustment. If in doubt, check with your supervisor or consult the manufacturer's manual. If adjustment is provided on the type you are installing, check the adjustments for the correct setting. These adjustments, often overlooked, allow for adequate pressure plate travel and proper clearance between the release levers and disk when the clutch is operated. The first adjustment insures proper movement of the pressure plate in relation to the cover. With the use of a special fixture or a striaghtedge and scale as shown in figure 8-8, begin by turning the adjusting capscrews until you obtain the proper clearance between the plate and straightedge as shown.

The second adjustment positions the release levers and allows the release bearing to contact the levers simultaneously while maintaining adequate clearance of the release levers and disk or pressure plate cover. There are two methods used for this adjustment. One is with adjusting screws located in the ends of the release levers. The other method is to place the pressure plate assembly on a flat surface, and, measuring the height of the levers as shown in figure 8-9, adjust by loosening the locknut and turning the adjusting screw to change the lever height. After adjusting, make sure the locknuts are staked with a punch to keep them from coming loose during operation.

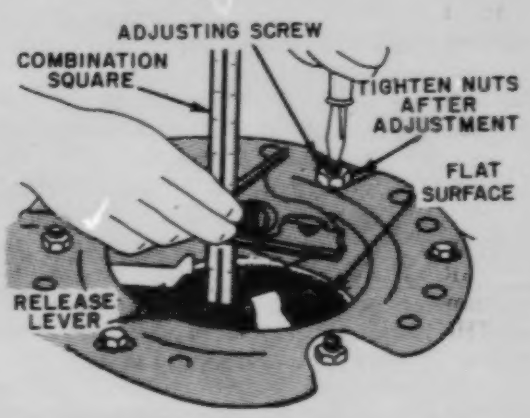
The clutch release bearing and sleeve is usually of the sealed type and factory packed (lubricated). Some heavy-duty vehicles have a throwout bearing which can be lubricated from an outside source. Here, the only problem involved would be either overlubrication or no lubrication. The release bearing sleeve or carrier requires little or no maintenance, although it should be checked for wear at the lugged or collar end where the fork or yoke comes in contact with the sleeve. If the bearing or carrier is found to be defective, it should be replaced.



81.536

Figure 8-8.—Pressure plate adjustment.

Reassembly should be done making sure that the old pressure plate assembly, if used, is reinstalled in the same position by using the alinement marks made before disassembly. An old clutch shaft or alinement tool should be used to center the clutch disk before tightening the bolts that hold the pressure plate assembly to the flywheel. This will make it much easier to install the transmission. After completing the reassembly, adjust the linkage by following the manufacturer's recommended procedures and specifications.



81.537

Figure 8-9.—Pressure plate release lever adjustment.

TRANSMISSION

The transmission is located between the clutch housing and the propeller shaft, as shown in figure 8-1. The transmission transfers engine power from the clutch shaft to the propeller shaft, and allows the operator to control the power and speed of the vehicle by selecting various gear ratios.

Gears and their mechanical advantages are discussed in *Basic Machines,* NAVPERS 10624-A. The manual also explains how to compute the speed and reduction ratio of gears in a typical automotive transmission. The information provided in *Basic Machines* will also help you understand the operating principles of the constant mesh, synchromesh, and auxiliary transmissions discussed in the following paragraphs as well as other power transfer mechanisms described in this chapter.

CONSTANT MESH TRANSMISSION

To eliminate the usual transmission noise developed by the spur-tooth gears used in the sliding gear transmission (fig. 8-10), automotive manufacturers developed the constant-mesh transmission which contains helical gears (fig. 8-11).

In this type of transmission, certain countershaft gears are constantly in mesh with the main shaft gears. The main shaft meshing gears are arranged so that they cannot move endwise. They are supported by roller bearings so that they can rotate independently of the main shaft (fig. 8-12).

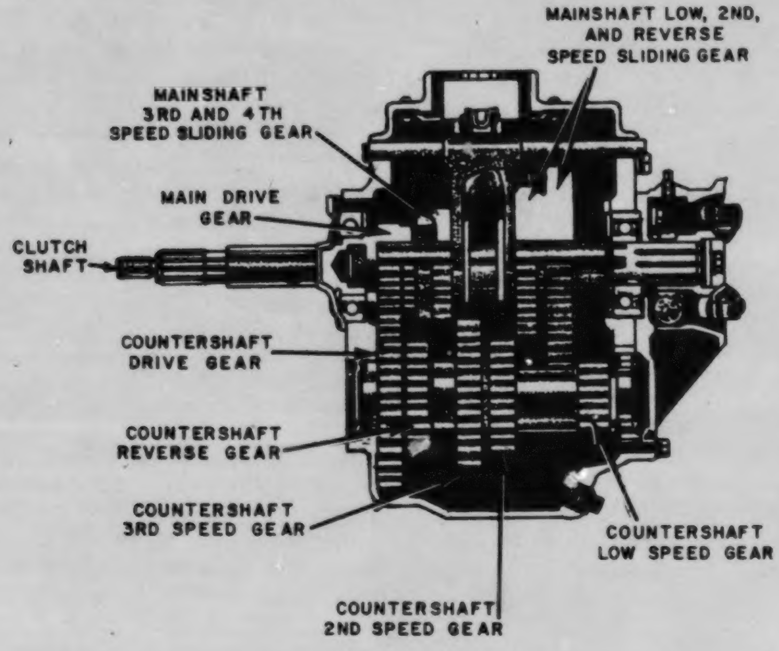
In operation, when the shift lever is moved to THIRD, the THIRD and FOURTH shifter fork moves the clutch gear (A, fig. 8-12) toward the THIRD speed gear (D, fig. 8-12). This engages the external teeth of the clutch gear with the internal teeth of the THIRD speed gear. Since the THIRD speed gear is meshed and rotating with the countershaft gear, the clutch gear must also rotate. The clutch gear is splined to the main shaft, and therefore, the main shaft rotates with the clutch gear. This principle is carried out when the shift lever moves from one speed to the next.

Constant-mesh gears are seldom used for all speeds. Common practice is to use such gears for the higher gears, with sliding gears for FIRST and REVERSE speeds, or for REVERSE only.

SYNCHROMESH TRANSMISSION

The three-speed synchromesh transmission (fig. 8-13) represents a design improvement to the constant-mesh type transmission in that it permits second and third speeds to be selected without clashing, by synchronizing the speeds of mating parts before they engage. First speed in this transmission is engaged by an ordinary dog clutch and reverse is engaged by a sliding gear. Second and third speeds are synchronized.

The synchromesh clutch (fig. 8-14), commonly referred to as a synchronizer, employs a combination cone clutch and a dog or gear clutch (sliding sleeve) to engage either the mainshaft or the input shaft, depending upon the gear selection. The cone clutch engages first, causing the mainshaft speed gear and mainshaft to rotate at the same speed, after which the sliding sleeve engages easily without clashing. This process is accomplished in one continuous operation when the operator releases the clutch and moves the shift control lever from one gear position to another. The construction of synchromesh transmissions varies with different manufacturers, but the principle of operation is the same. The sliding gear, which is splined to the transmission mainshaft with bronze internal cones on each side, is surrounded by a sliding sleeve. The sliding sleeve has internal teeth which mesh with the external teeth of the sliding gear, when actuated by the shift fork mounted in the external groove. Six spring-loaded balls mounted in the sliding gear fit in the internal groove of the sliding sleeve when the clutch is disengaged. This arrangement prevents the sliding sleeve from moving in


MAINSHAFT LOW, 2ND, AND REVERSE SPEED SLIDING GEAR
MAINSHAFT 3RD AND 4TH SPEED SLIDING GEAR
MAIN DRIVE GEAR
CLUTCH SHAFT
COUNTERSHAFT DRIVE GEAR
COUNTERSHAFT REVERSE GEAR
COUNTERSHAFT 3RD SPEED GEAR
COUNTERSHAFT LOW SPEED GEAR
COUNTERSHAFT 2ND SPEED GEAR

81.181

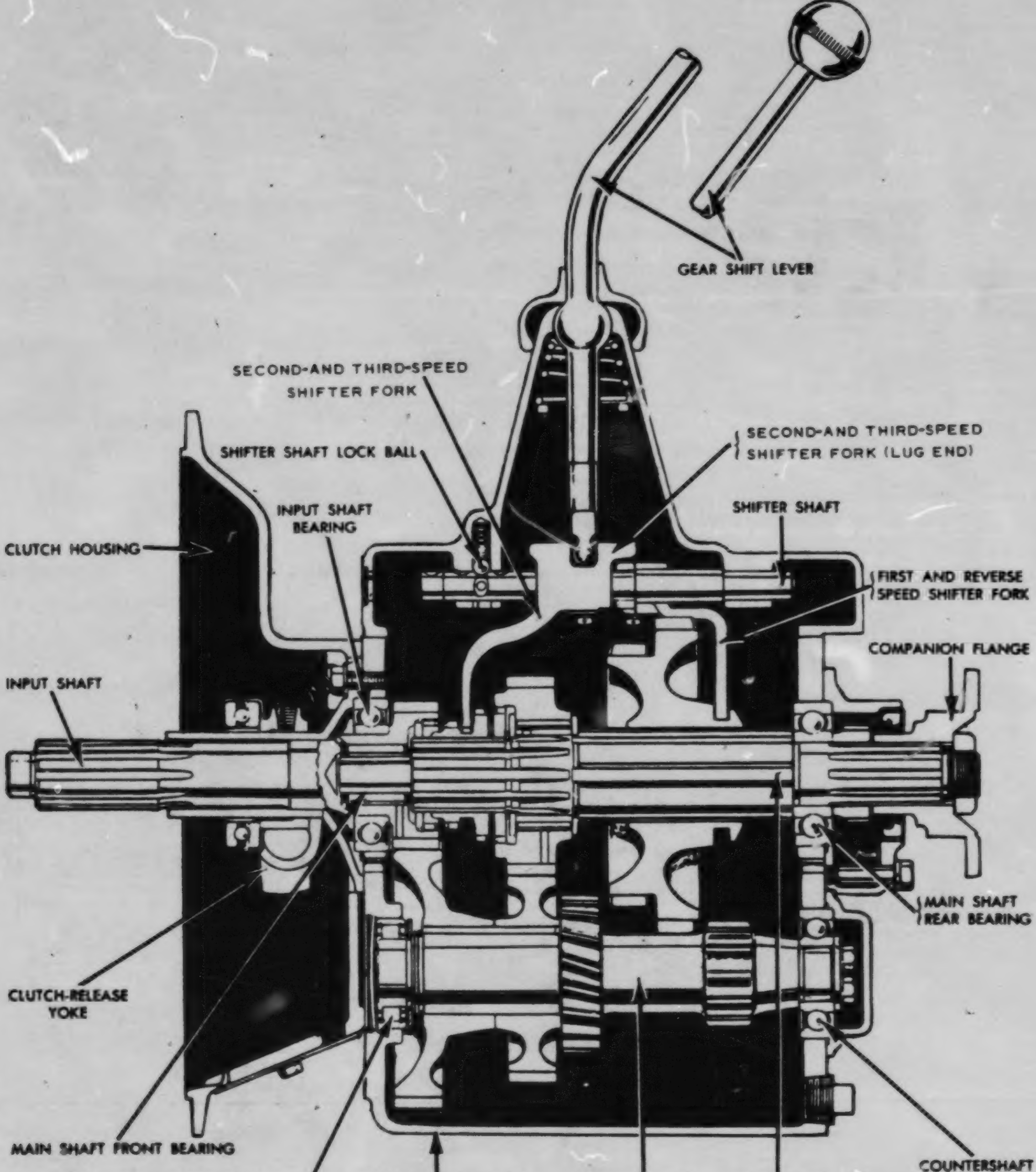
Figure 8-10.—Four-speed sliding gear transmission.

relation to the sliding gear until the latter has reached the end of its travel. The second speed gear and input shaft gear have external cones and teeth machined on their sides to engage the internal cones of the sliding gear and the internal teeth of the sliding sleeve.

When the transmission control lever is moved by the operator to the third speed or direct drive position, the shift fork moves the synchronizer unit forward until the internal cone on the sliding gear engages the external cone on the input shaft gear. This action brings the two gears to the same speed and stops forward travel of the sliding gear. The sliding sleeve then slides over the balls and silently engages the external teeth on the input shaft gear. When this occurs, the transmission input shaft gear and transmission mainshaft are locked together as shown in figure 8-14. When the transmission control lever is shifted to the second speed position, the synchronizer moves rearward and the same events take place by locking the second speed gear to the transmission mainshaft.

When shifting any manual transmission, proper use of the clutch is important. Rapid clutch engagement causes excessive strain on the power train. Additionally, releasing the clutch before the shift is completed will almost surely cause clashing of the gears. Shifting quickly after the clutch is released can cause the gears to clash. This is especially true when shifting into first or reverse gear and can happen when shifting to other speeds that are synchronized.

Figure 8-15 illustrates the gear arrangement and power flow through a five-speed synchronized transmission used in 5-ton 6 x 6 military trucks. The arrows indicate power flow and movement of the synchronizers during each speed selection. This transmission has five forward speeds and is synchronized in the upper four speed ranges. First and reverse are selected by use of a sliding spur gear that engages the


GEAR SHIFT LEVER
SECOND-AND THIRD-SPEED SHIFTER FORK
SECOND-AND THIRD-SPEED SHIFTER FORK (LUG END)
SHIFTER SHAFT LOCK BALL
INPUT SHAFT BEARING
SHIFTER SHAFT
CLUTCH HOUSING
FIRST AND REVERSE SPEED SHIFTER FORK
COMPANION FLANGE
INPUT SHAFT
MAIN SHAFT REAR BEARING
CLUTCH-RELEASE YOKE
MAIN SHAFT FRONT BEARING
COUNTERSHAFT FRONT BEARING
TRANSMISSION CASE
COUNTERSHAFT
MAIN SHAFT
COUNTERSHAFT REAR BEARING

81.183

Figure 8-11.–Cutaway view of a constant-mesh transmission assembly.

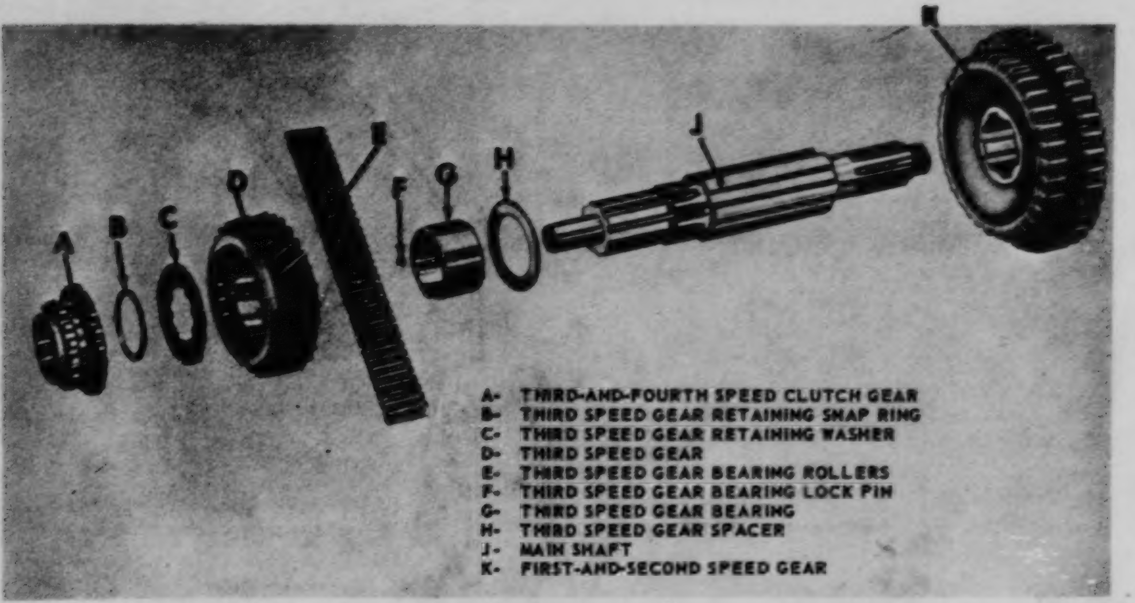

A
B
C
D
E
F
G
H
J
K
A- THIRD-AND-FOURTH SPEED CLUTCH GEAR
B- THIRD SPEED GEAR RETAINING SNAP RING
C- THIRD SPEED GEAR RETAINING WASHER
D- THIRD SPEED GEAR
E- THIRD SPEED GEAR BEARING ROLLERS
F- THIRD SPEED GEAR BEARING LOCK PIN
G- THIRD SPEED GEAR BEARING
H- THIRD SPEED GEAR SPACER
J- MAIN SHAFT
K- FIRST-AND-SECOND SPEED GEAR

Figure 8-12.—Disassembled main shaft assembly. 81.184

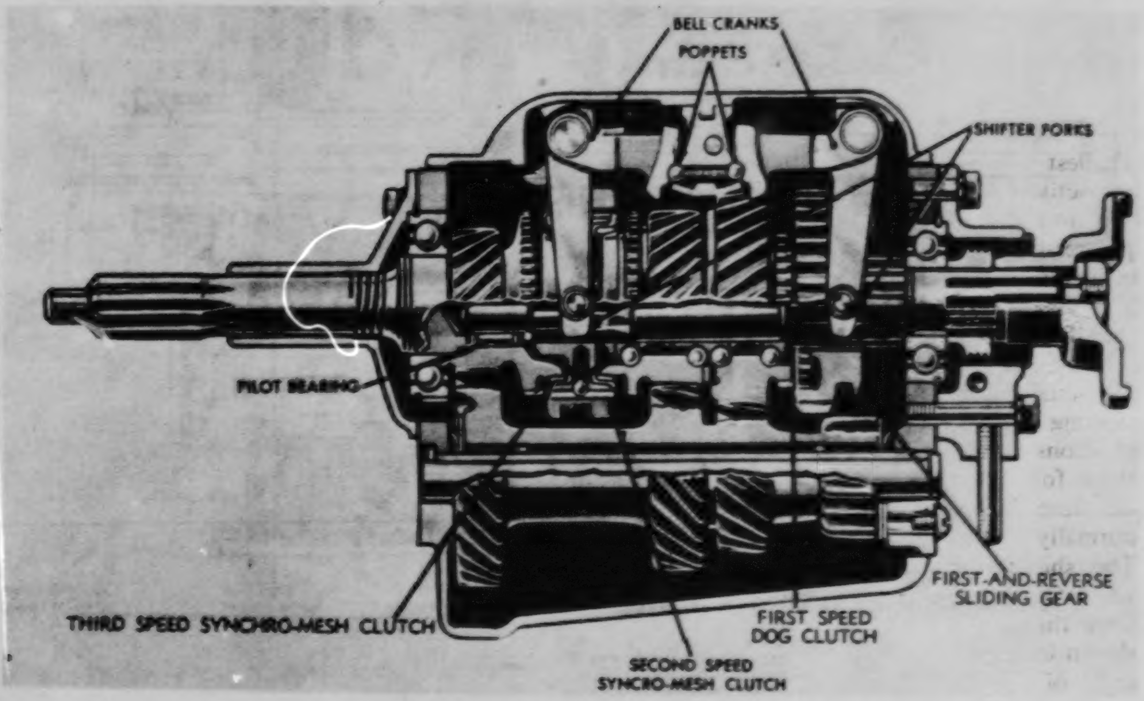
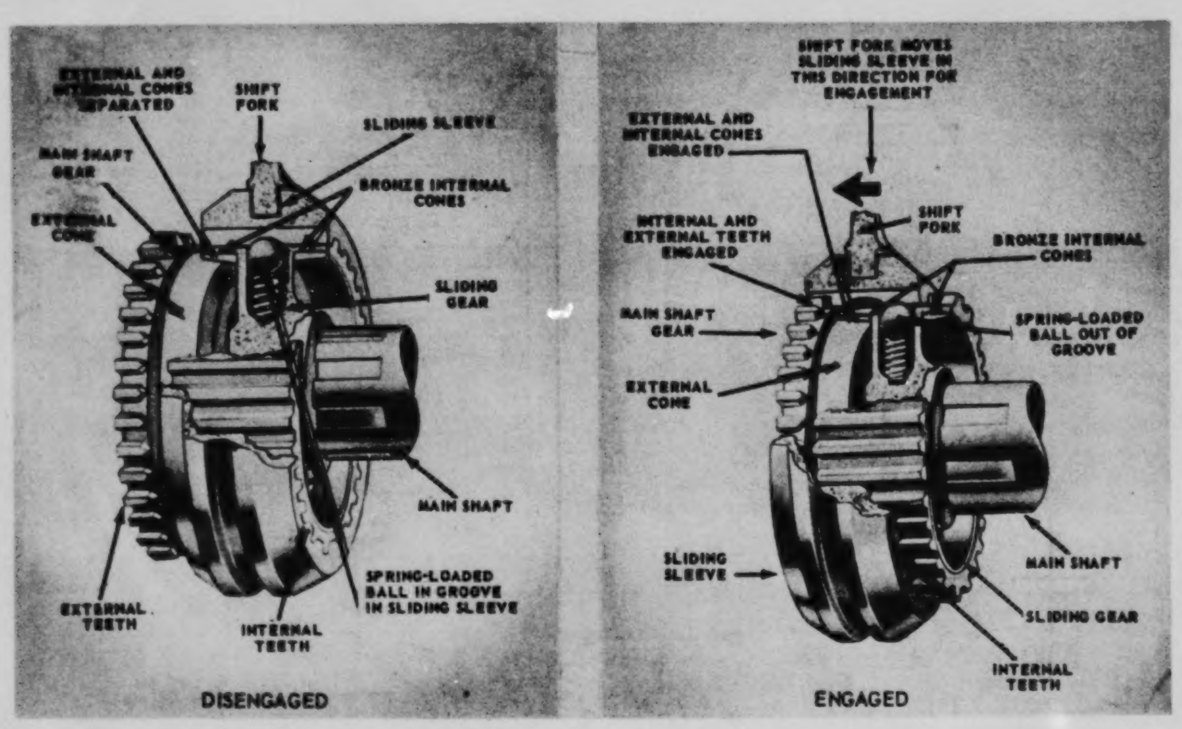

BELL CRANKS
POPPETS
SHIFTER FORKS
PILOT BEARING
FIRST-AND-REVERSE SLIDING GEAR
FIRST SPEED DOG CLUTCH
THIRD SPEED SYNCHRO-MESH CLUTCH
SECOND SPEED SYNCRO-MESH CLUTCH

Figure 8-13.—Three-speed synchromesh transmission. 81.186


EXTERNAL AND
INTERNAL CONES
SEPARATED
SHIFT
FORK
SLIDING SLEEVE
MAIN SHAFT
GEAR
BRONZE INTERNAL
CONES
EXTERNAL
CONE
SLIDING
GEAR
MAIN SHAFT
SPRING-LOADED
BALL IN GROOVE
IN SLIDING SLEEVE
EXTERNAL
TEETH
INTERNAL
TEETH
DISENGAGED
SHIFT FORK MOVES
SLIDING SLEEVE IN
THIS DIRECTION FOR
ENGAGEMENT
EXTERNAL AND
INTERNAL CONES
ENGAGED
SHIFT
FORK
INTERNAL AND
EXTERNAL TEETH
ENGAGED
BRONZE INTERNAL
CONES
MAIN SHAFT
GEAR
SPRING-LOADED
BALL OUT OF
GROOVE
EXTERNAL
CONE
SLIDING
SLEEVE
MAIN SHAFT
SLIDING GEAR
INTERNAL
TEETH
ENGAGED

81.185

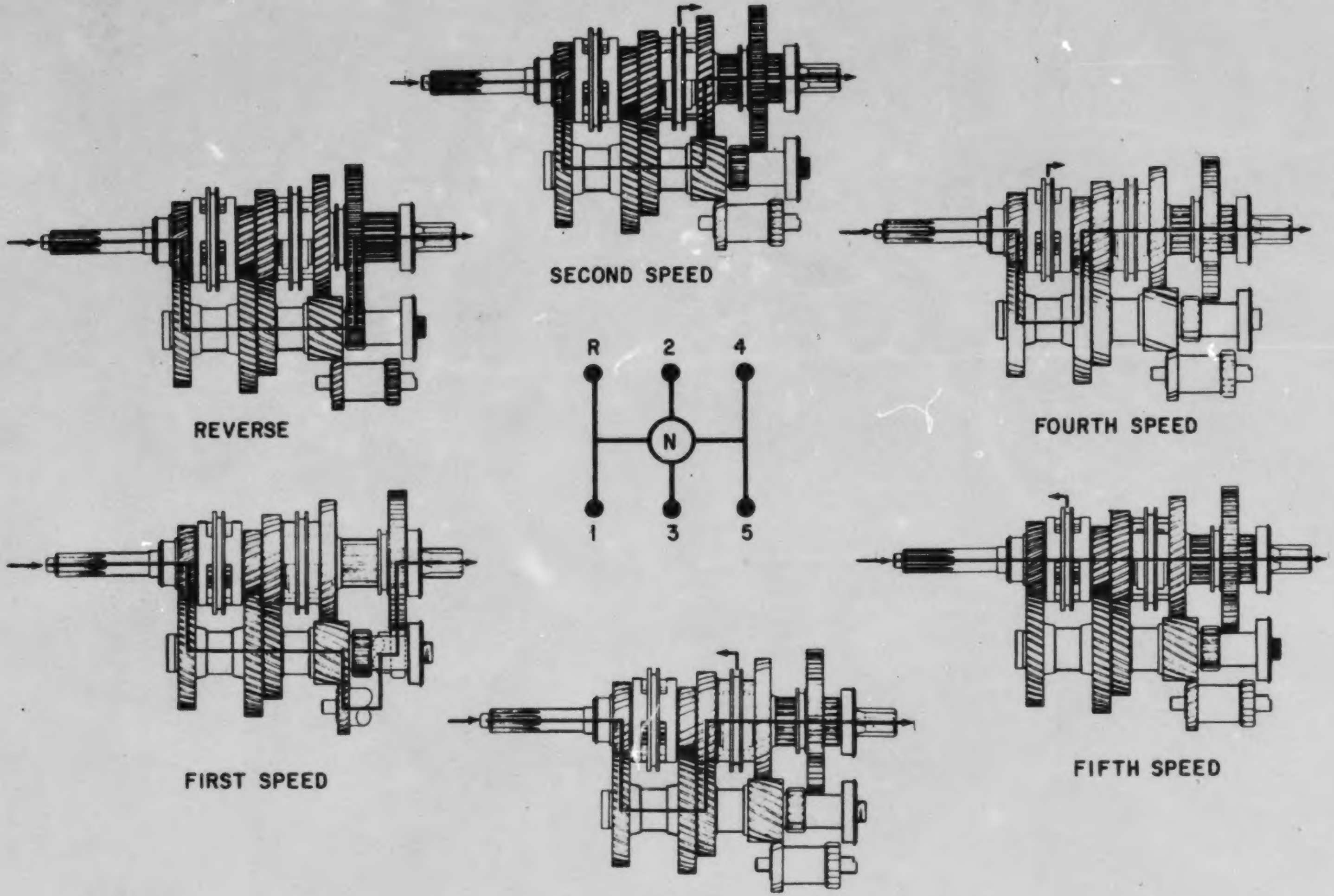
Figure 8-14.–Synchromesh clutch, disengaged and engaged.

smallest countershaft gear or the reverse idler respectively. By studying the illustration, you will notice that the countershaft gears used are progressively larger as speed selection progresses until direct drive, or fifth speed is engaged. At that time power flow is from the input shaft gear directly to the mainshaft.

Some transmissions are controlled by a steering column control lever (fig. 8-16). The positions for the various speeds are the same as those for the vertical control lever except that the lever is horizontal. This application is normally confined to three-speed transmissions. The shifter forks are pivoted on bellcranks which are turned by a steering column control lever through the linkage shown. The poppets shown in figure 8-13 engage notches at the inner end of each bellcrank. Other types of synchromesh transmissions controlled by steering column levers have shifter shafts and forks moved by a linkage similar to those used with a vertical control lever.

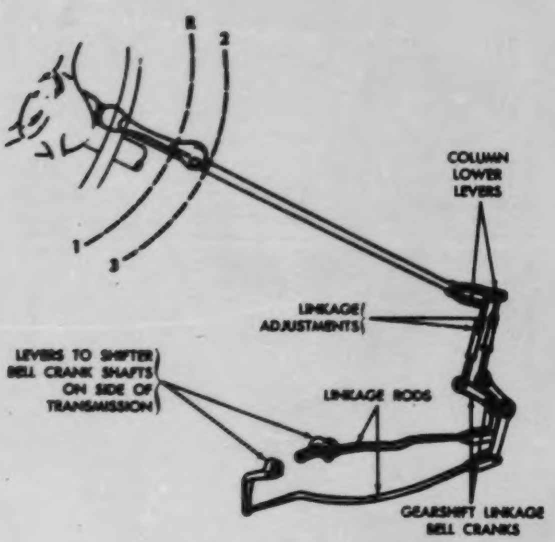
AUXILIARY TRANSMISSIONS

The auxiliary transmission (fig. 8-17) is used to provide additional gear ratios in the power train. This transmission is installed behind the main transmission and power flows directly to it from the main transmission, when of the integral type, or by a short propeller shaft (jack shaft) and universal joints. Support and alinement are provided by a frame crossmember. Rubber mounting brackets are used to isolate vibration and noise from the chassis. Shifting is accomplished by a lever which extends into the operator's compartment. Like the main


SECOND SPEED
REVERSE
FOURTH SPEED
R
2
4
N
1
3
5
FIRST SPEED
FIFTH SPEED
THIRD SPEED

81.538

Figure 8-15.—Power flow and gear arrangement in a five-speed synchronized transmission.


R
2
1
3
COLUMN LOWER LEVERS
LINKAGE ADJUSTMENTS
LEVERS TO SHIFTER BELL CRANK SHAFTS ON SIDE OF TRANSMISSION
LINKAGE RODS
GEARSHIFT LINKAGE BELL CRANKS

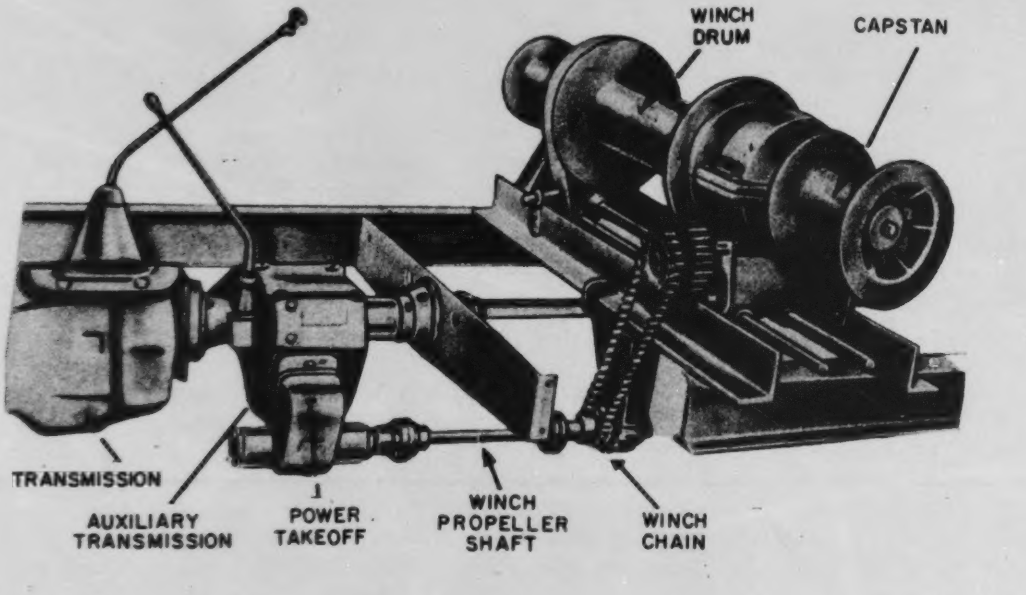
81.187

Figure 8-16.—Steering column transmission control lever and linkage.

transmission, the auxiliary transmission may have constant mesh gears and synchromesh clutches to allow easy shifting.

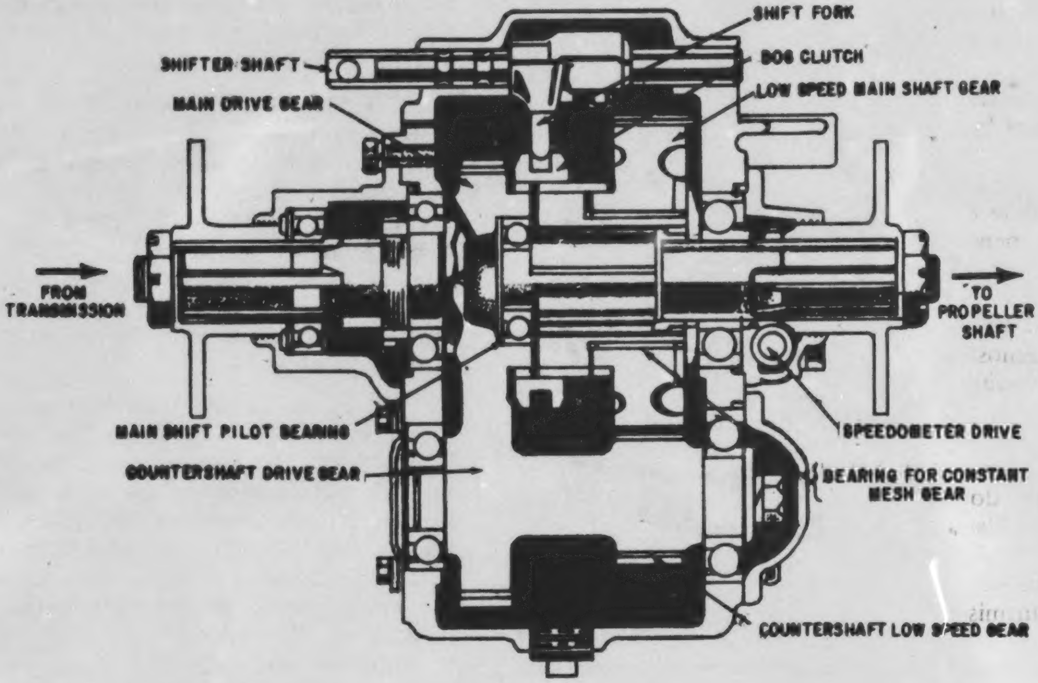
This transmission, when of the two-speed design, has a low range and a direct drive position. Three- and four-speed auxiliary transmissions commonly have at least one overdrive gear ratio. The overdrive position causes increased speed of the output shaft in relation to the input shaft speed. Overdrive is common on heavy-duty trucks used to carry heavy loads and travel at highway speeds.

The auxiliary transmission shown in figure 8-18 provides two speed ratios. When it is in the DIRECT SPEED position, power flows directly through the transmission and is controlled only by the main transmission. When the auxiliary transmission is shifted into LOW SPEED, vehicle speed is reduced and torque is increased. When the low speed of the auxiliary transmission is used with the lowest speed of the main transmission, the engine drives the wheels very slowly and with less engine horsepower.


WINCH DRUM
CAPSTAN
TRANSMISSION
AUXILIARY TRANSMISSION
POWER TAKEOFF
WINCH PROPELLER SHAFT
WINCH CHAIN

81.188

Figure 8-17.—Auxiliary transmission with power takeoff used for driving winch.


SHIFT FORK
DOG CLUTCH
LOW SPEED MAIN SHAFT GEAR
SHIFTER SHAFT
MAIN DRIVE GEAR
FROM TRANSMISSION
TO PROPELLER SHAFT
MAIN SHIFT PILOT BEARING
SPEEDOMETER DRIVE
COUNTERSHAFT DRIVE GEAR
BEARING FOR CONSTANT MESH GEAR
COUNTERSHAFT LOW SPEED GEAR

81.189

Figure 8-18.—Sectional view of an auxiliary transmission showing gear arrangement.

In this constant mesh auxiliary transmission, the main drive gear is part of the input shaft, and it is in constant mesh with the countershaft drive gear. A pilot bearing alines the main shaft output shaft with the input shaft. The low speed mainshaft gear runs free on the mainshaft when direct drive is being used, and is in constant mesh with the countershaft low speed gear. A gear-type dog clutch, splined to the main shaft, slides forward or backward when you shift the auxiliary transmission into high or low gear position.

In HIGH GEAR, when direct drive from the main transmission is being used, the dog clutch is forward and makes a direct connection between the input shaft and the mainshaft as shown in figure 8-18. When in LOW GEAR, the dog clutch is meshed with the low speed, mainshaft gear, and is disengaged from the maindrive gear.

The majority of auxiliary transmissions that you will encounter today are synchronized in the same manner as the main transmission.

TRANSMISSION TROUBLESHOOTING

Transmissions are designed to last for the life of the vehicle when lubricated and operated properly. Synchronizer units may eventually wear out because of the soft metal used in their construction. The bearings, shafts, and gears are heavily constructed to accommodate the rated capacity of the vehicle without failing.

The most common cause of failure results from shifting when the vehicle is not completely stopped or without waiting long enough to allow the gears to stop spinning after depressing the clutch pedal (rapid shifting). This slight clashing of gears may not seem significant at the time, but each time this occurs, small particles of the gears will be ground off and carried with the lubricant throughout the transmission. Since the synchronizer clutches are soft, these steel particles become embedded in their wearing surfaces and reduce the frictional quality of the clutch. This prevents the rapid synchronization of the other gears when shifting and will result in clashing or grinding. At the same time, other particles are causing damage to the bearings and gears by being mashed between the bearings and their races or gear teeth. This causes pitting, rough movement, and noise that soon results in failure of the power train component. When this happens, you will have to remove the component and replace the damaged or unusable parts.

As a first step in transmission service, diagnosis of the trouble should be made to pinpoint the malfunction in the unit. It is not always possible to determine the exact location of the trouble. When this happens, the unit must be removed from the vehicle so that it can be torn down and examined. In most cases, your first class or chief will make the final diagnosis if there is any doubt as to the nature of the trouble. Many times an operator will report transmission noise on the Operator's Trouble Report when, in fact, the noise may be coming from some other component of the vehicle's power train.

Noises that appear to come from the transmission but actually originate at some other point are many and varied. For example, unbalanced propeller shafts, defective wheel bearings, or damaged tires on a vehicle may cause noises which are transmitted to the transmission. These noises have no particular or characteristic sounds that would indicate their origin; they are therefore difficult to identify.

Torsional vibration is one of the most frequent causes of noises that appear to be in the transmission, but actually originate outside of it. Included among these possible outside torsional vibrations are:

1. Propeller shaft (drive shaft) out of balance
2. Worn universal joints
3. Drive shaft center bearings loose
4. Worn and pitted teeth on axle pinion and ring gear
5. Wheels out of balance
6. Worn spring pivot bearings
7. Loose frame or axle U-bolts
8. Engine crankshaft, flywheel, and/or clutch plate out of balance
9. Tires or wheels wobbly or mismatched

This list, along with other troubles that you have encountered in your own experience, can be used as a step-by-step guide in transmission noise troubleshooting. Make sure that all possibility of outside noise has been eliminated before you remove the transmission.

When analyzing a vehicle for transmission noise, raise the vehicle so that the driving wheels are clear of the deck. Start and operate the vehicle in all the speed ranges, including COASTING with the shift lever in neutral. Listen carefully for noises and try to determine the origin. There are other procedures for checking transmission noises that may be used. But the effectiveness of any procedure that is used depends largely upon the experience and good judgement of the mechanic doing the troubleshooting.

When it is determined that the noise is within the transmission, generally it is necessary to remove the transmission from the vehicle and disassemble it.

TRANSMISSION OVERHAUL

Because of the variations in construction of transmissions, different procedures in the removal, disassembly, repair, assembly, and installation must be followed. These operations generally require from 5 to 7 hours, depending on the procedure followed. If you are working on a vehicle with which you are not familiar, always check the manufacturer's manual.

Drain the lubricant from the transmission. Some manufacturers recommend flushing the transmission before removal. This is done by filling the transmission with a flushing oil and operating the engine with the transmission in neutral for several minutes. After this, drain the flushing oil from the transmission.

After removing the transmission assembly from the vehicle, note, or mark by scratching the case with a sharp pointed tool, any moist oil spots or unusually heavy accumulations of oil-soaked road mud; these are good clues to the location of small cracks or holes. Do not confuse these accumulations with those that result from leaking gaskets or oil seals. Oil dampness at a gasket or a seal is more or less normal on a transmission that has been in service for any length of time. After marking any spots indicating abnormal oil leakage, thoroughly clean the transmission case and make a close visual inspection to determine if any cracks or holes exist.

After the transmission is disassembled, clean all the parts thoroughly and individually.

Clean away all the parts of hardened oil, lacquer deposits, and dirt, paying particular attention to the small oil holes in the gears and to the lock ball bores in the shifter shaft housing. Remove all gaskets or parts of gaskets, using a putty knife or other suitable tool. Make sure that the metal gasket surfaces are not gouged or scratched.

After all parts of the transmission have been thoroughly cleaned, inspect them to determine whether they can be reused or have to be scrapped. The wear or damage to some of the parts will be evident to the eye, whereas, in others, it may be necessary to use tools or gages to determine their condition.

If you inspect the transmission parts, bear in mind that the inspection procedure has two objectives: first, to eliminate any part or parts that are unsuitable for use, or doubtful parts that may cause the premature failure of the overhauled transmission; second, and equally important, to reduce the wasteful practice of scrapping parts that still retain a high percentage of useful life.

If a transmission part is to be repaired, make sure it is done properly. Makeshift or temporary repairs should not be permitted, except in an emergency. The decision as to whether a part is to be repaired rests upon three factors: first, the practicality of the repair (that is, will the repair of the part return it to a near new condition?); second, the cost of the repair job as compared to the cost of a replacement; and third, the availability of the replacement part. Every effort should be made to salvage as many parts as possible.

Small holes or cracks in the transmission case, shifter shaft housing, or clutch housing may be repaired by welding or brazing, provided they do not extend into the bearing bores or mounting surfaces. These pieces are gray (cast) iron and a special technique is required to weld this material satisfactorily; ordinary welding methods and materials are not suitable.

To assemble a transmission, use a reverse procedure from that of disassembly. Check the manufacturer's manual for proper clearances and the wear limits of the parts. All leather oil seals should be soaked for at least 45 minutes in light oil prior to installation.

All parts, whether new or used, must be lightly coated with medium grade preservative lubricating oil. This is done immediately after inspection or repair. Oiling the parts gives them a necessary rust-preventive coating and facilitates the assembly operations.

Have all the necessary parts and gaskets at hand before the assembly operation begins. This guarantees that the transmission can be completely assembled without interruptions.

Test the transmission after it is assembled. If all parts are correctly assembled, the transmission gears will all rotate freely without evidence of binding. Use a suitable wrench to rotate the input shaft at least 10 full revolutions. Shift the transmission into all the speed ranges. If the transmission is noisy, extremely loose, or binds, it must be disassembled and further corrective measures taken.

TRANSFER CASES

Transfer cases are placed in the power trains of vehicles driven by all wheels. Their purpose is to provide the necessary offsets for additional propeller shaft connections to drive the wheels.

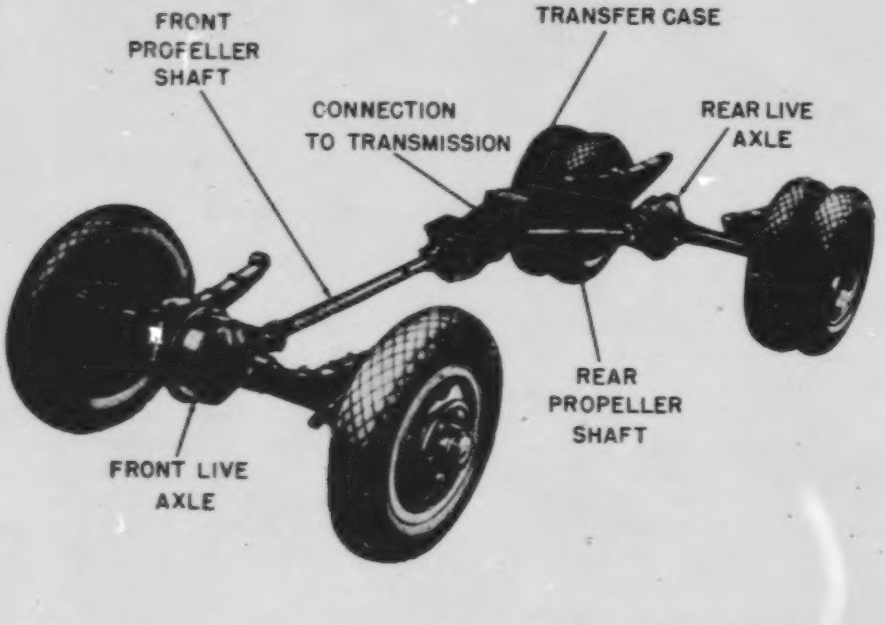
Transfer cases in heavier vehicles have two-speed positions and a declutching device for disconnecting the front driving wheels. Two-speed transfer cases like the one shown in figure 8-19 serve also as auxiliary transmissions.

Some transfer cases are quite complicated. When they have speed changing gears, declutching devices, and attachments for three or more propeller shafts, they are even larger than the main transmission. A cross section of a common type of two-speed transfer case is shown in figure 8-20.

This same type of transfer case is used for a 6-wheel drive vehicle. The additional propeller shaft connects the drive shaft of the transfer case to the rearmost axle assembly. It is connected to the transfer case through the transmission brake drum.

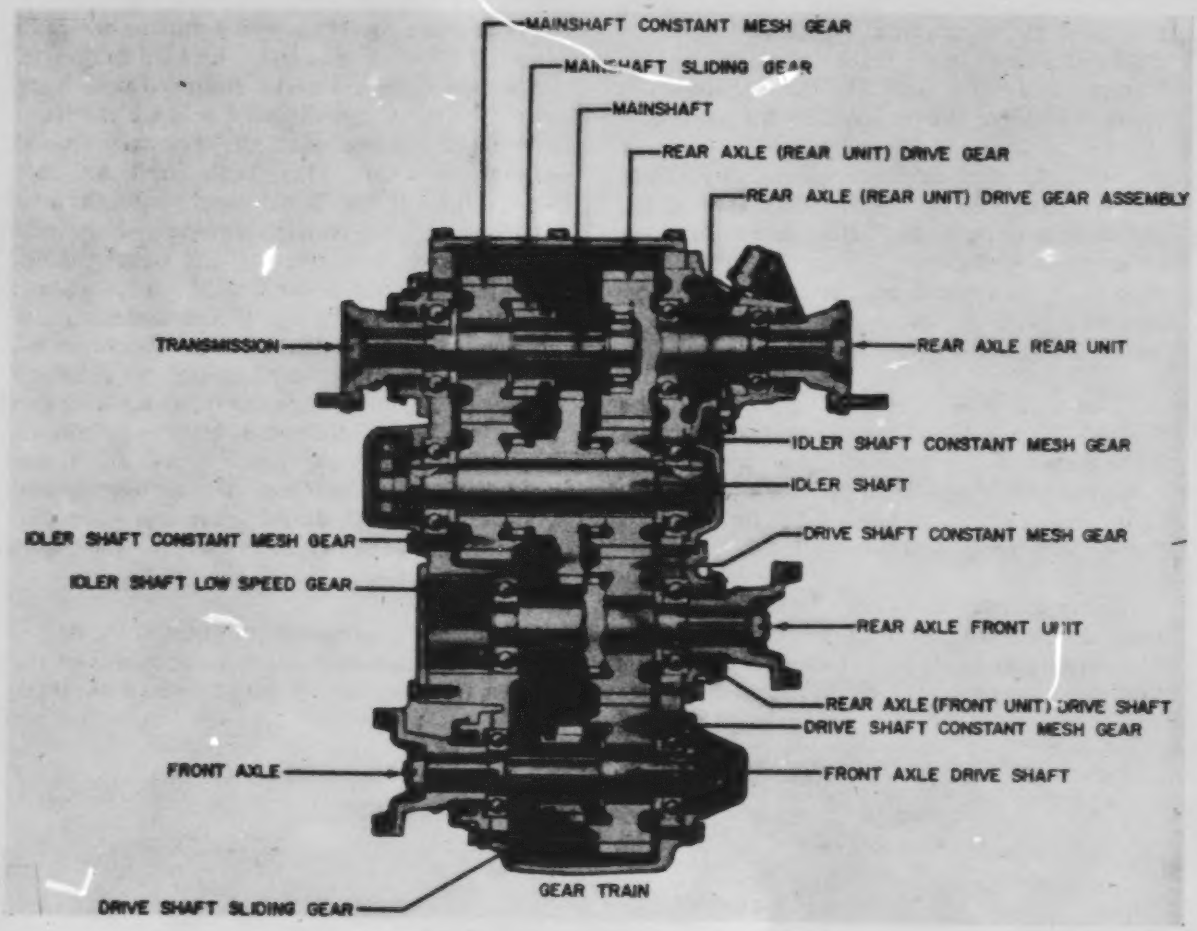
Some transfer cases contain an overrunning sprag unit (or units) on the front output shaft. The sprag unit is a form of overrunning clutch that permits power to be transmitted in one direction. Vehicles you will encounter with a sprag unit are equipped with a shifting device to allow all wheel drive in either forward or reverse. On all wheel drive vehicles equipped with sprag units, the transfer is designed to drive the front axle slightly slower than the rear axle. During normal operation, when both front and rear wheels turn at the same speed, only the rear wheels drive the vehicle. However, if the rear wheels should lose traction and begin to slip, they tend to turn faster than the front wheels. As this happens, the sprag unit automatically engages so that the front wheels also drive the vehicle. The sprag unit simply provides an automatic means of engaging the front wheels in drive whenever additional tractive effort is required. There are two types of sprag-unit-equipped transfers: a single-sprag-unit transfer and a double-sprag-unit transfer. Essentially, both types work in the same manner.

The first indication of trouble within a transfer case, as with other components of the power train, is usually noisy operation. If an



81.190

Figure 8-19.–Transfer case installed in a 4-wheel drive truck.


MAINSHAFT CONSTANT MESH GEAR
MAINSHAFT SLIDING GEAR
MAINSHAFT
REAR AXLE (REAR UNIT) DRIVE GEAR
REAR AXLE (REAR UNIT) DRIVE GEAR ASSEMBLY
TRANSMISSION
REAR AXLE REAR UNIT
IDLER SHAFT CONSTANT MESH GEAR
IDLER SHAFT
IDLER SHAFT CONSTANT MESH GEAR
DRIVE SHAFT CONSTANT MESH GEAR
IDLER SHAFT LOW SPEED GEAR
REAR AXLE FRONT UNIT
REAR AXLE (FRONT UNIT) DRIVE SHAFT
DRIVE SHAFT CONSTANT MESH GEAR
FRONT AXLE
FRONT AXLE DRIVE SHAFT
GEAR TRAIN
DRIVE SHAFT SLIDING GEAR

81.191

Figure 8-20.—Cross section of a two-speed transfer case.

operator reports trouble, make a visual inspection before removing the unit from the vehicle. Check for such things as oil level, oil leakage, and water in the oil.

Make sure the shift lever linkages are inspected. If the shift lever linkages are bent or improperly lubricated, it will be hard to shift the transfer case or, in some cases, will make shifting impossible. Make sure other possible troubles such as clutch slippage, damaged propeller shaft, and damaged axles have been eliminated.

Worn or broken gears, worn bearings, and excessive end play in the shafts will cause noisy operation of the transfer case. When it is decided that the trouble is within the transfer case, remove the unit from the vehicle for repairs.

Make sure the transfer case is thoroughly cleaned before disassembly of the unit begins. When the unit is disassembled, clean each part with an approved cleaning solvent. Inspection of the individual parts should follow the same procedure as outlined for transmissions. Avoid waste by reusing old parts that are in good condition.

If you are not thoroughly familiar with a particular make and model of transfer case, you should check the manufacturer's repair manual to insure that proper adjustments and assembly procedures are followed.

POWER TAKEOFFS

Power takeoffs (PTO) are used in the power train to operate auxiliary equipment. You will commonly find these units on dump trucks, fuel tankers, and vehicles equipped with winches. They can be found attached to, and driven from, the transmission, auxiliary transmission, or transfer case. A common type of PTO is the single-gear, single-speed type shown in figure 8-21. This unit may be bolted to an opening provided in the side of the auxiliary transmission case as shown in figure 8-17. Shims or spacers are often used to insure that the proper contact is maintained between the teeth. The sliding gear of the PTO can then mesh with, and be driven by, the countershaft gear inside the auxiliary transmission, when engaged by the vehicle operator. The operator, by use of a control lever, can cause the gear to slide in or out of mesh with the transmission gear. The spring-loaded ball (poppet) holds the shaft in position.

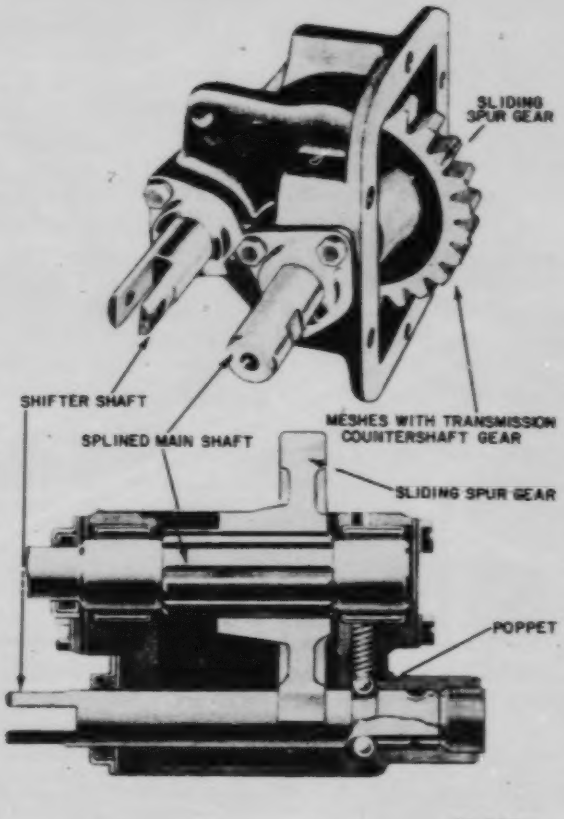


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Figure 8-21.–Single-speed, single-gear, power takeoff.

On some vehicles you will find PTO units with gear arrangements that will give two speeds forward and one in reverse. Several forward speeds and a reverse gear are usually provided in a PTO unit used to operate a winch or hoist. Operation of this kind of PTO unit is similar to that of the single-speed unit.

Faulty operation of a PTO is usually caused by damaged or broken linkage. To prevent this, care must be exercised when shifting. Trying to engage the unit with the transmission gears turning can chip the teeth, and rapid clutch engagement can break its housing. Rapid shifting may bend the linkage. Forcing the control lever can bend or break the linkage.

Adjustment and lubrication of the linkage to compensate for wear are normally all the maintenance required for the PTO unit. The gears and bearings are lubricated from the transmission sump.

To remove the PTO unit for repairs, disconnect the drive shaft and shift linkage and drain the transmisison. Next, remove the bolts securing the unit to the transmission case. Don't misplace or lose any shims or spacers that may be used between the housings. Once the unit is removed from the vehicle, the inspection and repair procedures are the same as for a transmission.

When replacing the unit, you may find it necessary to check the clearance between the transmission teeth and the PTO gear teeth. Carefully follow the manufacturer's procedures when installing shims or spacers to prevent damage or failure of the unit.

DRIVE LINES

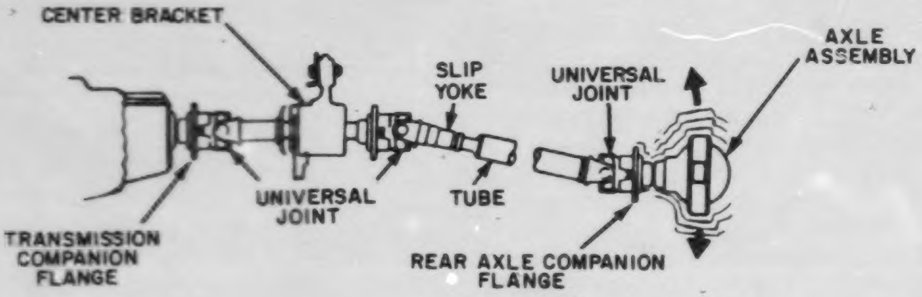
Drive line assemblies contain propeller shafts, universal joints, slip joints, and in some cases center support bearings. These assemblies provide a path through which power is transmitted from the transmission to the drive axle assemblies or auxiliary equipment. Vehicles having a long wheel base are equipped with a propeller shaft that extends from the transmission or transfer case to a center support bearing, and a propeller shaft that extends from the center support bearing to the rear axle (fig. 8-22).

PROPELLER SHAFTS

Propeller shafts, which may be of a solid or tubular type, require little or no maintenance. Solid shafts are normally used where high shaft speeds are unnecessary. They are used extensively to power auxiliary equipment such as winches and hydraulic pumps. The hollow shaft is used almost exclusively to transmit power to the axles on automotive vehicles. The hollow shaft, because it rotates at high speed, must be balanced to prevent vibration and premature bearing failure in the transmission and differential assemblies.

The propeller shaft can be either open or enclosed, depending on the type of drive employed. The open propeller shaft is used in what is known as HOTCHKISS drive. This type of drive is common to the equipment that you will encounter in the Navy.

In some cases, torque rods and stabilizer bars are used with the Hotchkiss drive. Torque rods, metal rods, or bars are used to insure accurate alinement of an axle with the frame. Stabilizer bars are used to cause both springs, front, or rear, to act together on curves. Vehicles, with leaf springs (flexible members that support the weight of the vehicle) at the rear, are pushed forward by the driving thrust applied at the front ends of the springs that are attached to the frame. The HOTCHKISS drive (fig. 8-23) requires that such springs be rigid enough to withstand the twisting action (torque) of the rear axle and the driving and braking forces that the springs transmit to the frame. As a consequence of the rigidness, the springs are relatively flat. Rear-end torque tends to rotate the axle housing in a direction opposite to that of the wheel rotation when torque is applied to the wheels and is especially great during sudden stops and starts. In cases where coil springs rather than leaf springs are used at the rear, the torque reaction is transmitted by torque arms which extend from the axle housing forward to a frame member. In some vehicles equipped with rear coil springs, the torque is transmitted to the frame by means of two lower control arms and a single upper control arm. The forward ends of the lower control arms are fastened to brackets on the frame side rails, while the rear ends are attached to brackets on the rear axle housing. The upper control arm is attached to one or both frame side rails as well as to the axle housing. If it is attached to only one side rail, there is a tie rod from the other side rail to the opposite end of the axle housing.



81.539

Figure 8-22.—Drive line with center support bearing.

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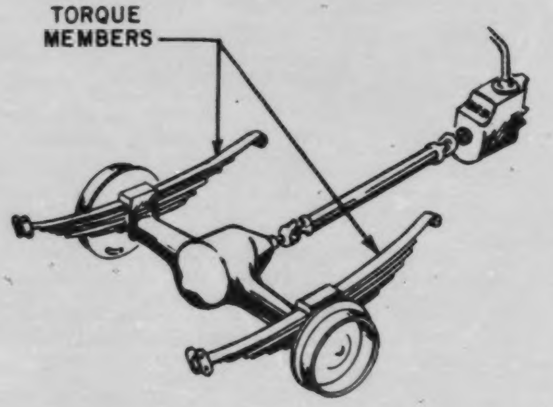

TORQUE
MEMBERS

81.193

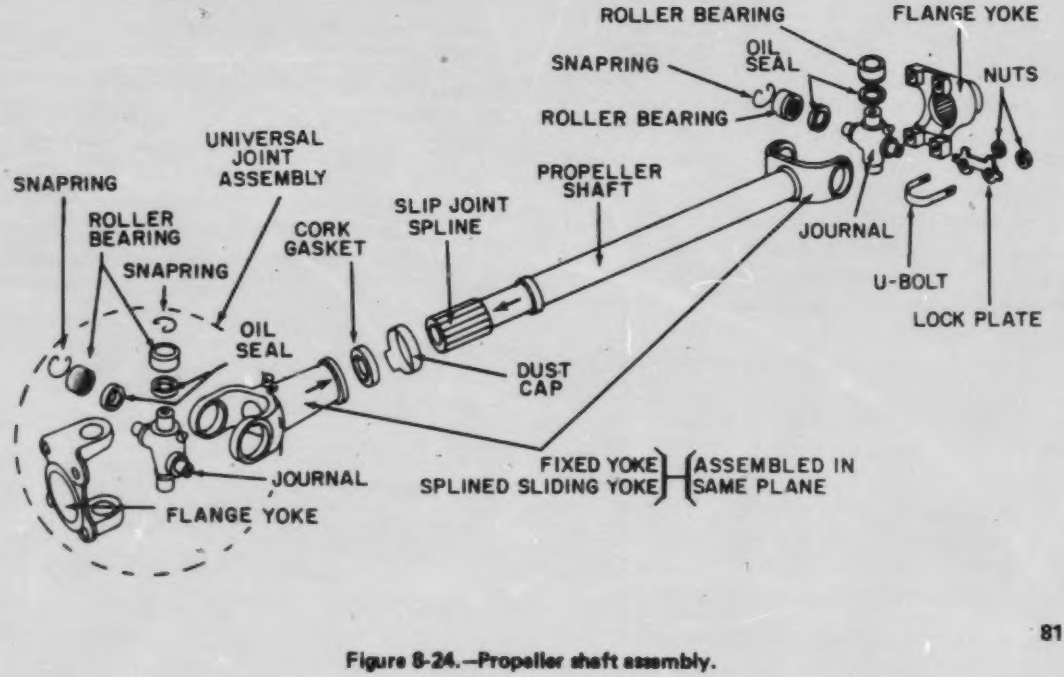
Figure 8-23.–Hotchkiss drive.

UNIVERSAL JOINTS

A universal joint acts as a flexible coupling between two shafts and permits one shaft to drive another shaft that is at an angle to it. The universal joint is flexible in the sense that it will permit power to be transmitted while the angle of the shaft is being continually varied.

A conventional universal joint assembly is composed of three fundamental units–a journal (cross) and two yokes (fig. 8-24). The two yokes are set at right angles to each other and are joined by the journal in a manner similar to the universal sockets in your toolbox. This construction permits each yoke to pivot on the journal and also permits the transmission of the rotary motion from one yoke to the other. As a result, the universal joint can transmit the power from the engine through the shaft to the rear axle, even though the engine is mounted in the frame at a higher level than the rear axle, which is constantly moving up and down in relation to the engine (fig. 8-22).

Two universal joints are placed in a propeller shaft to eliminate the speed fluctuations of the shaft that occur while the shaft is at an angle to the power source. They are placed at a 90° angle to each other and one counteracts the action of the other when in motion.


ROLLER BEARING
FLANGE YOKE
SNAPRING
OIL SEAL
NUTS
ROLLER BEARING
UNIVERSAL JOINT ASSEMBLY
SNAPRING
PROPELLER SHAFT
ROLLER BEARING
SLIP JOINT SPLINE
CORK GASKET
JOURNAL
SNAPRING
U-BOLT
OIL SEAL
LOCK PLATE
DUST CAP
JOURNAL
FIXED YOKE
SPLINED SLIDING YOKE
ASSEMBLED IN SAME PLANE
FLANGE YOKE

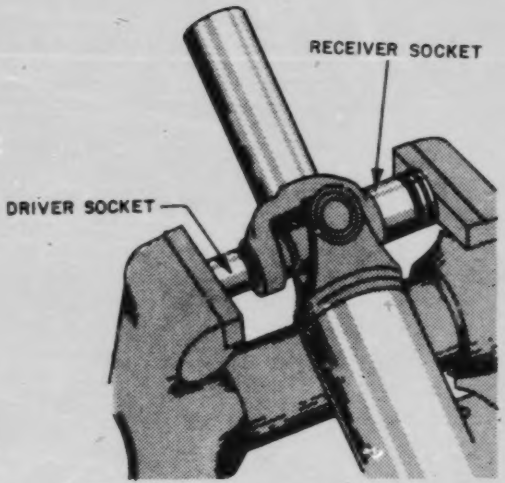
81.540

Figure 8-24.–Propeller shaft assembly.

You will notice two different types of universal joints in figure 8-24. They differ mainly in the way the journal is attached to the yoke and flange. When disassembling a universal joint like the one on the right of the figure, you must first remove the nuts from both U-bolts. Support the propeller shaft while doing this to prevent its falling when the U-bolts are removed. Maintain a hold on the bearing caps and push the propeller shaft forward into the slip joint. This will free the propeller shaft from the flange. Now carefully remove the bearings, making sure you do not lose any of the individual needle bearings. The omission of only one needle bearing during reassembly will cause rapid wear of the universal joint. A good method of keeping the needles in place in the cap is to fill the center cavity of the cap with heavy grease. If the needles fall from the caps during disassembly or reassembly, replace them so that there are an equal number in each cap.

Some universals must be disassembled in order to be repacked, whereas others have a grease fitting for this purpose. Do not lubricate with a high pressure grease gun, because it will damage the seals. Be careful with the grease retainers or seals when removing the journal, because you may have to use them again. To remove the journal, you must first remove the snaprings from the back of the journal bearings. After you have removed the snaprings, place the universal joint in a vise or press. Then select a socket from your tool kit that is slightly smaller in its outside diameter than the bearing cap. Select another socket that is slightly larger in its inside diameter than the outside of the bearing. Now place the sockets at opposite bearings so the smaller socket acts as a bearing driver and the larger socket as a bearing receiver when the vise jaws come together as illustrated in figure 8-25. Close the vise jaws gradually until both bearings are free of the yoke and can be removed. Use the same procedure then on the two remaining bearings. If the grease retainers are to be reused, be careful not to push the bearing too far. If a damaged grease retainer is placed in the universal joint, the grease will soon be thrown out, resulting in a worn journal.

Before the universal joint shown on the left of figure 8-24 can be disassembled, the yoke must be loosened from the universal joint flange. The same procedure is then followed as with the first universal joint.



81.541

Figure 8-25.—Universal joint removal.

The slip joints in some vehicles will have "matching marks" that are either stamped or painted on during the initial assembly and balancing operation. These marks should always be in line, since this will aline the joints in their original balanced position. Some mechanics will center punch all matching parts of a drive line before disassembling or separating the parts. This enables them to reassemble and install the component parts in their original position. If no alining marks show, you must assemble the slip joint so that the yokes of the "U" joints at each end are parallel. Slip joints require very little maintenance outside of keeping the dust cap tight and an occasional "shot" of grease.

CENTER SUPPORT BEARINGS

When two or more propeller shafts are connected together in tandem, their alinement is maintained by a rubber bushed center support bearing secured to a crossmember of the frame. A typical center support bearing assembly is shown in figure 8-26. This bearing is prelubricated and sealed and requires no further lubrication; it must be replaced if it is damaged. Some support bearings on heavy-duty vehicles have lubrication fittings. Even though lubrication extends the useful life of the support bearings, they eventually wear out. The first indication of support bearing failure is excessive chassis vibration at low speed caused by the bearing turning with the shaft in the rubber support.

Should you encounter a faulty support bearing, replacement procedures are usually limited to separating the drive shafts, unbolting the bearing support from the frame, and sliding the bearing and support assembly from the shaft.

Prior to discarding any parts, determine if your parts room has the entire assembly or just the bearing. If only the bearing is available, disassemble the unit by gently prying the bearing and dust shield out of the rubber support. Next, remove the dust shield from the bearing. All parts that are to be reused should be cleaned in a solvent.

Inspect all parts for wear and damage. If the rubber support shows any evidence of hardening, cracking, or tearing, it should be replaced. Some manufacturers recommend that a waterproof grease be placed in the retainers on both sides of the bearing, not for a lubricant but to exclude water and dust from the bearing. Before securing the bearing support to the crossmember, check the applicable shop manual to determine if shims are required for alinement purposes.

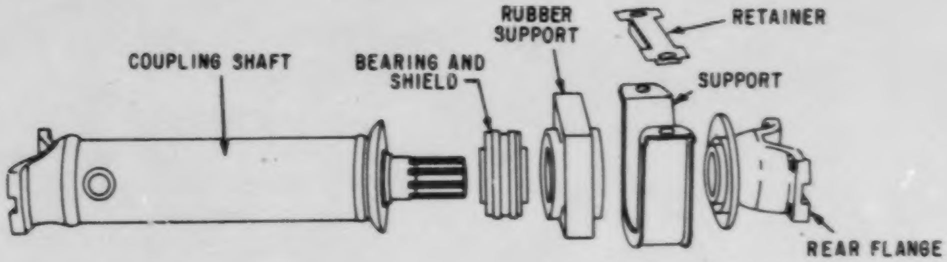
When reassembling support bearings, care should be exercised to insure that proper alinement of the drive line is maintained. This will prevent abnormal wear of the universal joints.

A bearing similar to the center bearing is often used with long drive lines containing a single propeller shaft. This bearing, called a PILLOW BLOCK BEARING, is commonly used in drive lines that power auxiliary equipment. Its purpose is to provide support for the shaft and maintain alinement. When used at or near the center of the shaft, it reduces the whipping tendency of the shaft at high speeds or when under heavy loads.

The construction of pillow blocks varies. The simplest form as used on solid PTO shafts is no more than a steel sleeve with a bronze bushing.

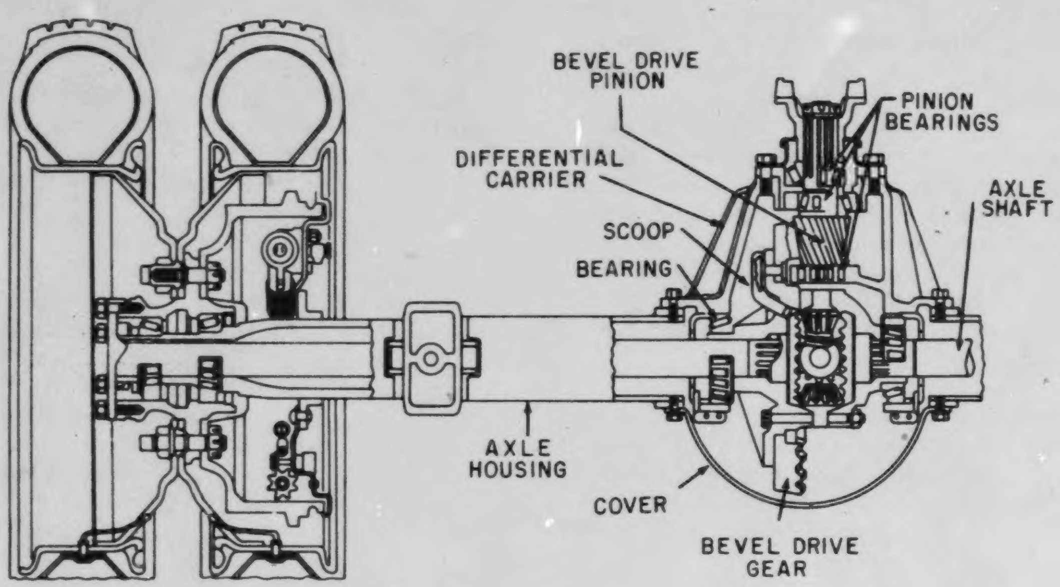
DRIVE AXLE ASSEMBLY

The power from the engine is transmitted in a line parallel to the length of the vehicle through the transmission and propeller shafts to the drive axle assembly (fig. 8-27). This assembly consists of the axle housing, final drive, differential gears (differential assembly), and axles.



81.542

Figure 8-26.—Center support bearing.



81.543

Figure 8-27.—Drive axle assembly.

AXLE HOUSING

The axle housing may be of one-piece construction or it may be the split type. The former, known as the banjo type because of its appearance, is by far the more common. This is the type illustrated in figure 8-27. Notice that openings, both front and rear, are provided in the center housing. The front opening is closed by the differential carrier, while that at the rear is closed by a spherical cover plate.

Since the assembly must carry the weight of the vehicle, the axle housing in heavy trucks and tractors is a heavy cast unit. In light-duty trucks it may be a combination of cast and steel tube; in general, the center or differential and final drive case is a cast and machined unit, whereas the axle housings themselves may be welded or extruded steel tubing. Items such as brake backing plate mounting flanges, spring mounting plates, and accessory units may be riveted, welded or cast into the axle housing. Inspection covers are often provided through which the internal parts can be inspected or through which they can be removed or installed. Lubricant filler plugs are usually incorporated in the housing inspection cover.

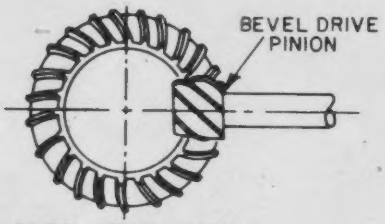
To prevent pressure buildup when the axle becomes warm, a breather valve or vent is provided atop the housing. Without this valve, the resulting pressure could force the axle lubricant past the rear wheel oil seals and damage the brake linings. The valve is so constructed that air may pass in or out of the axle housing, yet dirt and moisture are kept out.

FINAL DRIVE

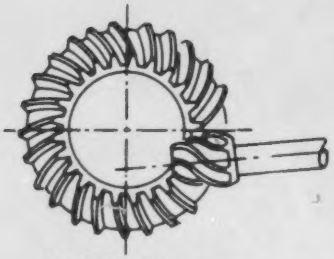
The final drive transfers the power from the propeller shaft to the differential. The function of the final drive, commonly called the ring gear and pinion, is to change by 90 degrees the direction of the power transmitted by the propeller shaft to the differential. It also provides a fixed reduction between the speed of the propeller shaft and the axles driving the wheels.

The major components of the final drive include the pinion gear, connected to the propeller shaft, and a bevel or ring gear which is bolted or riveted to the differential carrier. To maintain accurate alinement and proper tooth contact, the ring gear and differential assembly are mounted in bearings.

The reduction or gear ratio of the final drive is determined by dividing the number of teeth on the ring gear by the number of teeth on the pinion gear. In passenger cars, this final speed reduction or rear axle ratio may vary from 3:1 to 5:1. A ratio of 3.89:1 would mean that the propeller shaft turns 3.89 times while the axle shafts are turning once. In trucks, the reduction varies from about 5:1 to 11:1. The bevel drive pinion (fig. 8-27) is supported by two tapered roller bearings mounted in the differential carrier. This pinion shaft is straddle mounted. This means that a bearing is located on each side of the pinion shaft teeth. Oil seals prevent the loss of lubricant from the housing where the pinion shaft and axle shafts protrude. As a CM, you will encounter the final drive gears of the spiral bevel and hypoid design, as shown in figure 8-28.



SPIRAL BEVEL GEAR



HYPOID GEAR

81.195

Figure 8-28.—Types of final drives.

Spiral Bevel Gear

Spiral bevel gear final drives are used extensively in trucks and occasionally in automobiles. This design allows for constant tooth contact between the bevel and pinion gears. It also necessitates the use of heavy lubricants.

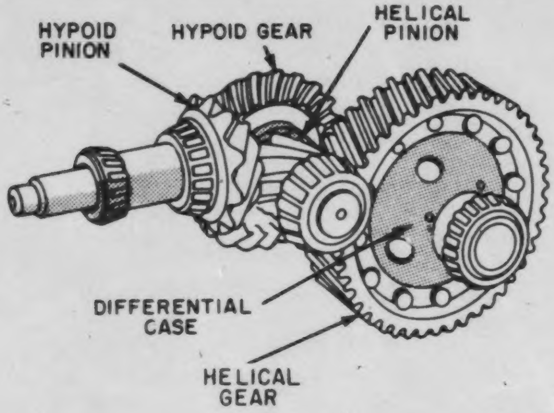
Hypoid Gear

The hypoid gear final drive is an improvement or variation of the spiral bevel design and is commonly used in light and medium duty trucks and almost all domestic automobiles. With the use of this gear, automotive manufacturers were able to eliminate a portion of the hump common to the floorboard of the automobile.

As you can see in figure 8-28, the pinion meshes with the ring gear below the centerline and is at a slight angle (less than 90 degrees). This angle and the use of heavier (larger) teeth permit an increased amount of power to be transmitted while the size of the ring gear and housing remain constant. The tooth design is similar to the spiral bevel but includes some of the characteristics of the worm gear. This permits the reduced drive angle. The hypoid gear teeth have a more pronounced curve and a steeper angle, resulting in larger tooth areas and more teeth to be in contact at the same time. This gear has high frictional quality but is quiet in operation. The wiping action of the teeth causes heavy tooth pressure that requires the use of heavy-duty lubricants.

Double Reduction Final Drive

In the final drives illustrated in figure 8-28, there is a single fixed gear reduction. This is the


HYPOID PINION
HYPOID GEAR
HELICAL PINION
DIFFERENTIAL CASE
HELICAL GEAR

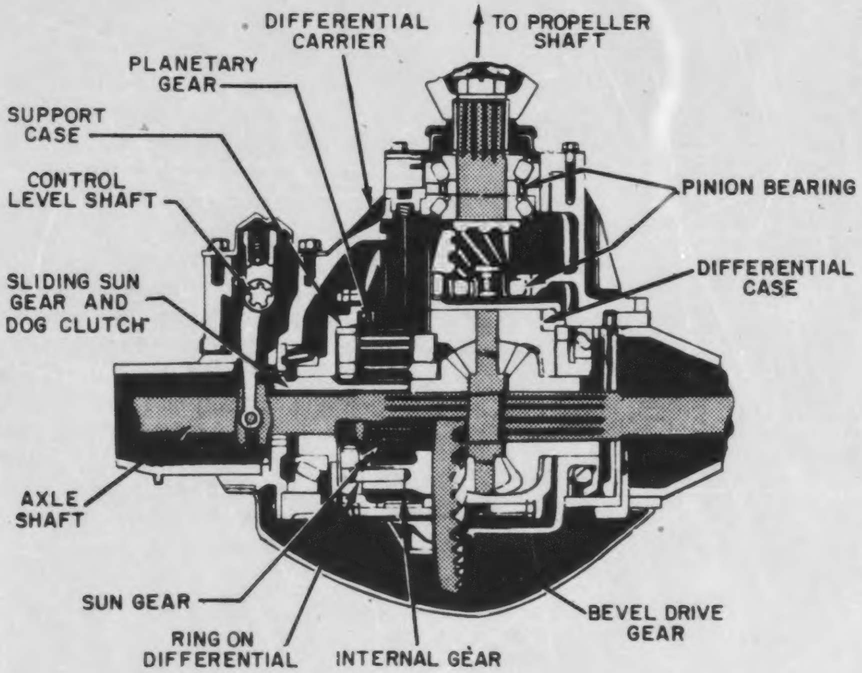
81.544

Figure 8-29.—Double-reduction final drive gears.

only gear reduction in most cars and trucks between the drive shaft and the wheels. On many heavy-duty trucks, double-reduction final drive gears are used. With this arrangement (fig. 8-29), it is not necessary to have a very large ring gear to get the necessary gear reduction. The first gear reduction is obtained through a pinion and ring gear as the ordinary reduction final drive. Here, a hypoid gear arrangement is shown, although other types are used. Notice that a helical pinion is mounted on the shaft with the ring gear. The second gear reduction is the result of the helical pinion fixed rigidly to the ring gear, driving the large helical gear attached to the differential case. Double-reduction final drives are used on military design vehicles you will encounter that are rated at 2 1/2-ton and 5-ton capacity. Many commercially designed vehicles of this size use a single- or double-reduction final drive with provisions for two speeds to be incorporated.

Two-Speed Final Drive

The two-speed or dual-ratio rear axle assembly shown in figure 8-30 is used to supplement the gearing of the other drive train


DIFFERENTIAL CARRIER
TO PROPELLER SHAFT
PLANETARY GEAR
SUPPORT CASE
CONTROL LEVEL SHAFT
PINION BEARING
SLIDING SUN GEAR AND DOG CLUTCH
DIFFERENTIAL CASE
AXLE SHAFT
SUN GEAR
RING ON DIFFERENTIAL
INTERNAL GEAR
BEVEL DRIVE GEAR

81.545

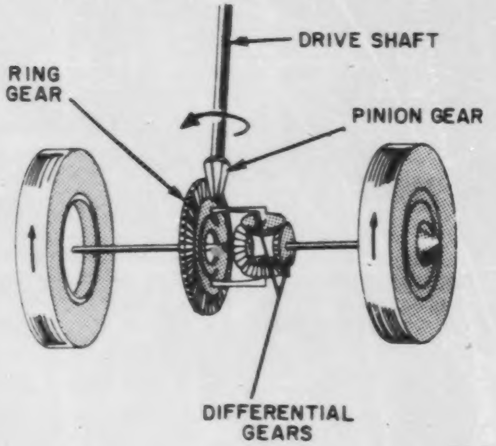
Figure 8-30.—Two-speed or dual-ratio rear axle.

components, and is used in vehicles with a single drive axle. The range or speed of this axle can be selected at will by the operator with a button on the shifting lever of the transmission or a lever through linkage. The two-speed unit is installed so that when in high range, the final drive functions the same as usual. When shifted into low range by the operator, the gear arrangement allows for a reduction in the speed of the axles in relation to the ring gear or bevel drive gear. This unit is popular because its cost is less than that of a transmission that would provide the same gear selection.

With a two-speed unit, and a five-speed transmission, 10 different forward speeds are available. This provides a gear ratio high enough to permit pulling a heavy load up steep grades and a low ratio to permit the vehicle to run at high speeds with a light load or no load.

DIFFERENTIAL

Another important unit in the power train is the differential, which is driven by the final drive. As indicated in figure 8-31, the differential is located between the axles and permits one axle shaft to turn at a different speed from that of the other. At the same time, the differential transmits power from the final drive to both axle shafts. The variation in axle shaft speeds is necessary when the vehicle rounds a corner or travels over uneven ground. As a vehicle travels around a curve, the outer wheel must travel faster and farther than the inner wheel. Without the differential, one rear wheel would be forced to skid when turns are made, resulting in excessive tire wear as well as making the vehicle more difficult to control. A differential will also compensate for tires of different sizes when used on a driving axle by making the surface speed of the tires equal. However, the use of tires of different sizes is not recommended since they cause extra wear of the differential from additional rotation of the gears.



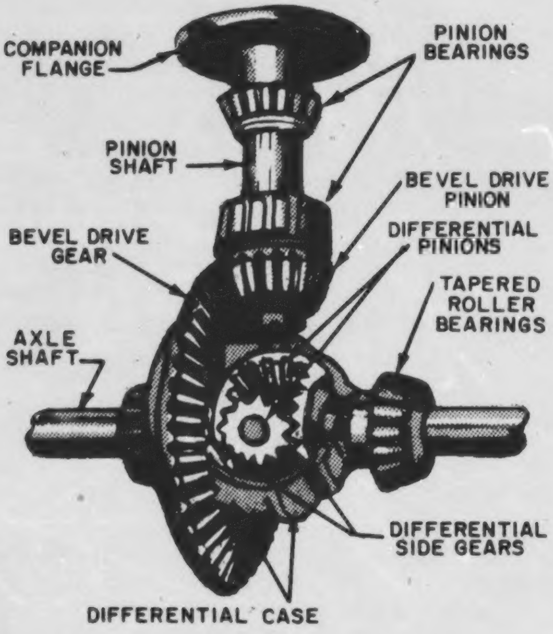
81.546

Figure 8-31.–Principle of conventional differential operation.

Figure 8-31 illustrates in simple form the operating principle of a conventional type differential as used in most vehicles. Note that the drive is from the ring gear to whose case two of the differential gears are attached. These two gears drive two other slightly larger differential gears, one of which is splined to the inner end of each axle shaft. The two gears attached to the differential case are known as differential pinions, and the others are called side gears. When the vehicle turns or travels over bumps, the differential gears move in relation to one another, allowing each wheel to rotate at different speeds. Figure 8-32 illustrates an actual differential with the case that holds the pinion gears. Notice that there are four pinions used, instead of two as shown in figure 8-31. The differential case rotates in tapered roller bearings, which are mounted in the differential carrier. The carrier holds the final drive and differential (fig. 8-27). The final drive and differential are inserted in the opening of the axle housing, and the differential carrier is fastened to the housing; a gasket is used to make the joint oiltight.

DRIVING AXLES

Axles are classified as either LIVE or DEAD. The live axle is used to transmit power. The dead axle only serves as a support for part of the vehicle while providing a mounting for the wheel assembly. Many commercial trucks and truck-tractors have dead axles on the front, whereas practically all passenger cars use


COMPANION FLANGE
PINION BEARINGS
PINION SHAFT
BEVEL DRIVE PINION
DIFFERENTIAL PINIONS
BEVEL DRIVE GEAR
TAPERED ROLLER BEARINGS
AXLE SHAFT
DIFFERENTIAL SIDE GEARS
DIFFERENTIAL CASE

81.196
Figure 8-32.—Conventional differential.

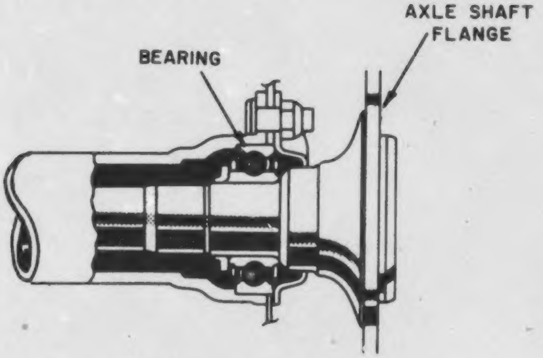
independent front wheel suspension and have no front axle as such.

The shaft in a live axle assembly may or may not actually support part of the weight of a vehicle, but it does drive the wheels connected to it. A live axle is involved with steering when it is a front drive axle. Some live rear axles are also designed to steer. The rear axle of conventional passenger cars is a live axle, while in a four-wheel drive vehicle like a JEEP or truck, both front and rear axles are live. In some six-wheel vehicles, all three axles are live axles.

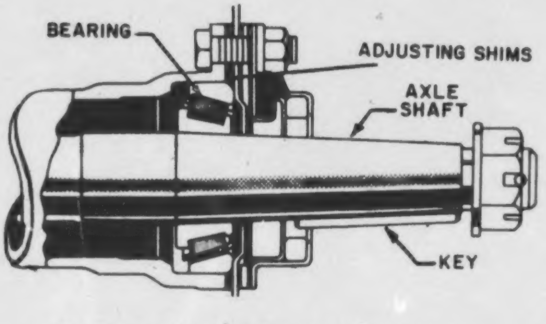
The two common types of driving axles you will encounter are known as the semifloating and full-floating. When the axle shaft supports part of the weight, the housing supports the remainder, and when the shaft supports none of the weight, the housing supports it all.

Semifloating Axle

The semifloating axle is used in passenger vehicles and light trucks. In vehicles equipped with this type of axle, the shaft as well as the housing supports the vehicle weight. Here, the inner end of the axle shaft is carried by the side gear in the differential housing. The outer end is carried by a bearing located between the shaft and the housing. This bearing transfers the load from the shaft to the housing, and is either a tapered roller or a ball type. The axle shafts (fig. 8-33) are flanged or tapered on the ends. When the tapered axle is used, the drum and hub are pressed onto the shafts, using keys to prevent the assemblies from turning on the shafts. In some cases, the outer end of the axle may have serrations or splines to correspond with those used on the drum and hub assembly. Should the axle break with this type of axle assembly, the wheel can separate from the vehicle.


AXLE SHAFT FLANGE
BEARING

BALL BEARINGS AND FLANGE SHAFT


BEARING
ADJUSTING SHIMS
AXLE SHAFT
KEY

TAPERED ROLLER BEARINGS AND SHAFT

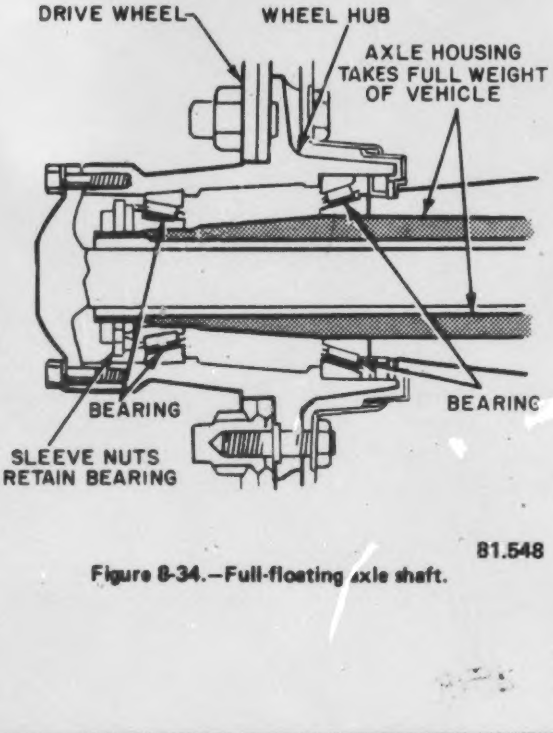
81.547
Figure 8-33.—Semifloating axle installation.

Full-Floating Axle

The full-floating axle (fig. 8-34) is used in many heavy-duty trucks. The drive wheel is carried on the outer end of the axle housing by a pair of tapered roller bearings. The bearings are located outside the axle housing. In this way, the axle housing takes the full weight of the vehicle and absorbs all stresses or end thrust caused by turning, skidding and pulling. The axle shaft only transmits torque from the differential. The shaft is connected to the drive wheel through a bolted flange. This allows the axle shaft to be removed for servicing without removal of the wheel.

All wheel drive vehicles use a full-floating axle that provides power to the front wheels. The front wheels are driven through a driving axle assembly very similar to the rear axle. Power is transmitted from the transfer case to the front axle by a propeller shaft. The differential housing may be set offcenter in the axle housing to permit the propeller shaft to pass beside the engine oil pan, and maintain sufficient road clearance without excessive height at the front end of the vehicle.

The principal difference between front and rear drive axles is that in front wheel drives provisions must be made for steering. Since the front wheels must turn on the spindle arm pivots, they are driven by the axle shafts through universal joints. Illustrated near the center of figure 8-35 is the conventional type universal joint. The spider and bearings of this universal joint are identical to those used in some drive shafts and are interchangeable. This type of universal joint is normally limited to use in light-duty vehicles.


DRIVE WHEEL
WHEEL HUB
AXLE HOUSING TAKES FULL WEIGHT OF VEHICLE
BEARING
BEARING
SLEEVE NUTS RETAIN BEARING

81.548

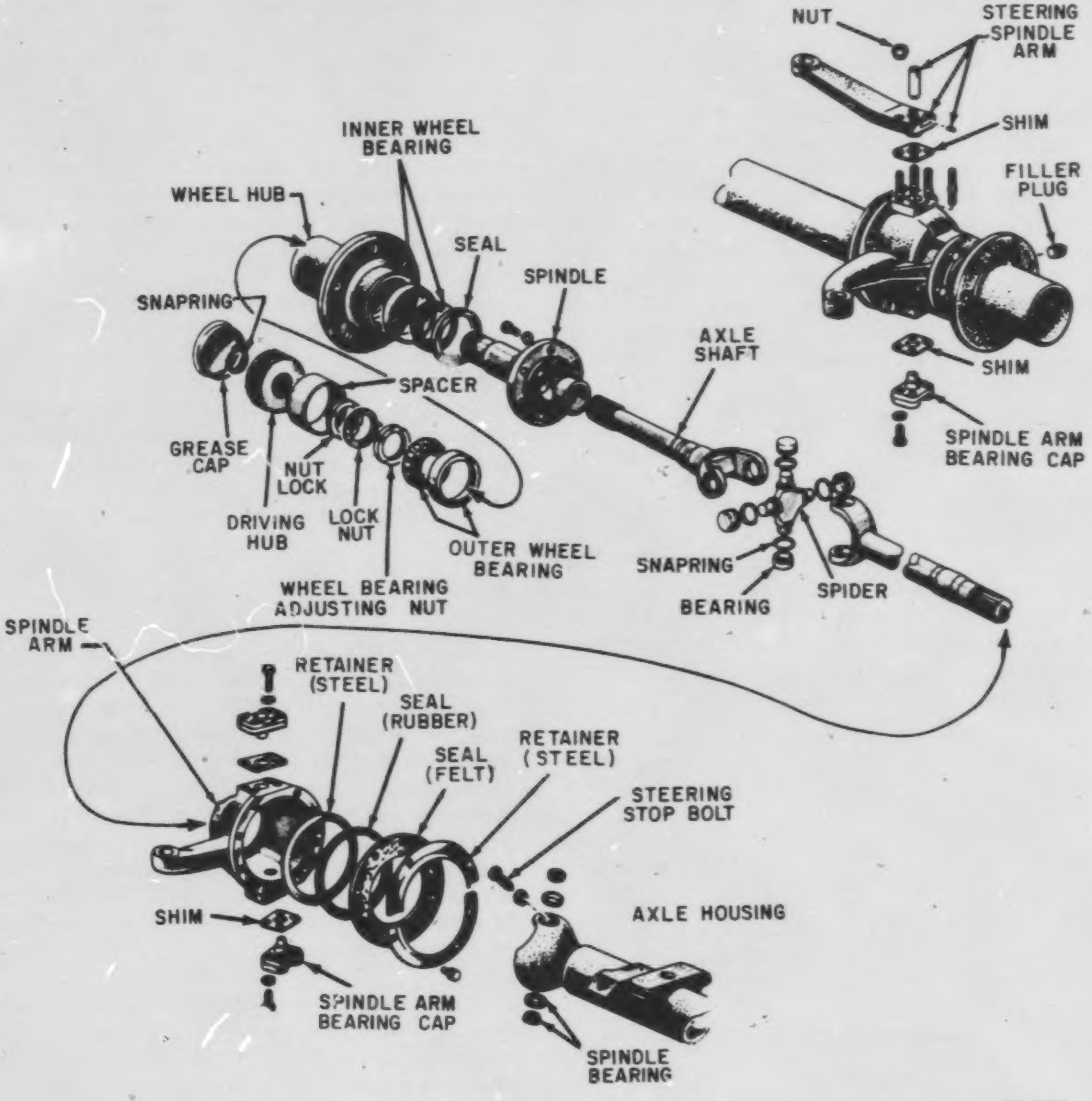
Figure 8-34.–Full-floating axle shaft.

Other types of universal joints are used in the axles of heavy-duty vehicles. The types you will encounter in military designed vehicles are the REZEPPA and BENDIX-WEISS shown in figure 8-36. These constant velocity universal joints are designed to prevent the speed fluctuations common with the conventional type of universal joint.

DRIVE AXLE MAINTENANCE

Drive axle assemblies, like transmissions, in a properly operated vehicle seldom cause any maintenance problems. By maintaining proper wheel bearing adjustment (if of the full-floating type), keeping the proper lubrication level, and occasionally changing a seal or gasket, the assembly will normally last as long as the vehicle in which it is used. The axle vents should be checked at each scheduled PM. Should they fail to work because of dirt or other foreign material, leaks will occur at the seals and gaskets in the axle assembly.

The first hint of existing trouble is generally an unusual noise in the axle housing. To properly diagnose the trouble, however, you must determine the source of the noise and under what operating conditions the noise is most pronounced. Defective universal joints, rough rear wheel bearings, or tire noises may be improperly diagnosed by the inexperienced mechanic as differential trouble. Some clue may be gained as to the cause of trouble by noting whether the noise is a growl, hum, or knock; whether it is heard when the car is operating on a straight road, or on turns only; and whether the noise is most noticeable when the engine is


NUT
STEERING SPINDLE ARM
SHIM
FILLER PLUG
INNER WHEEL BEARING
WHEEL HUB
SEAL
SPINDLE
SNAPRING
AXLE SHAFT
SPACER
SHIM
SPINDLE ARM BEARING CAP
GREASE CAP
NUT LOCK
DRIVING HUB
LOCK NUT
OUTER WHEEL BEARING
WHEEL BEARING ADJUSTING NUT
SNAPRING
BEARING
SPIDER
SPINDLE ARM
RETAINER (STEEL)
SEAL (RUBBER)
SEAL (FELT)
RETAINER (STEEL)
STEERING STOP BOLT
AXLE HOUSING
SHIM
SPINDLE ARM BEARING CAP
SPINDLE BEARING

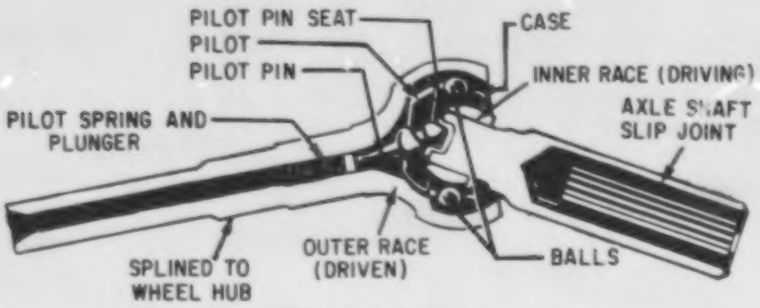
81.549

Figure 8-35.—Front drive axle.

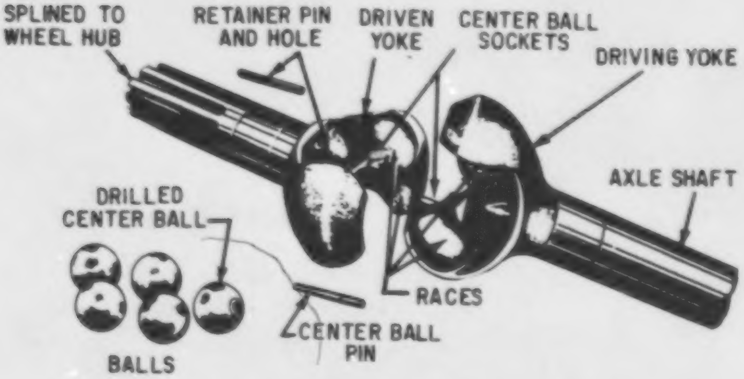
driving the vehicle or when it is coasting with the vehicle driving the engine.

A humming noise in the differential generally means the ring gear or pinion needs an adjustment. An imporperly adjusted ring gear or pinion prevents normal tooth contact between the gears and therefore produces rapid gear tooth wear. If the trouble is not corrected immediately, the humming noise will gradually take on growling characteristics, and the ring gear and pinion will probably have to be replaced.

It is very easy to mistake tire noise for differential noise. Tire noise will vary according


PILOT PIN SEAT
PILOT
PILOT PIN
PILOT SPRING AND PLUNGER
CASE
INNER RACE (DRIVING)
AXLE SHAFT SLIP JOINT
SPLINED TO WHEEL HUB
OUTER RACE (DRIVEN)
BALLS

REZEPPA UNIVERSAL JOINT


SPLINED TO WHEEL HUB
RETAINER PIN AND HOLE
DRIVEN YOKE
CENTER BALL SOCKETS
DRIVING YOKE
AXLE SHAFT
DRILLED CENTER BALL
RACES
CENTER BALL PIN
BALLS

BENDIX-WEISS UNIVERSAL JOINT

5.34

Figure 8-36.–Constant velocity universal joints.

to the type of pavement the vehicle is being driven on, while differential noise will not. To confirm a doubt as to whether the noise is caused by tire or differential, drive the vehicle over various types of pavement.

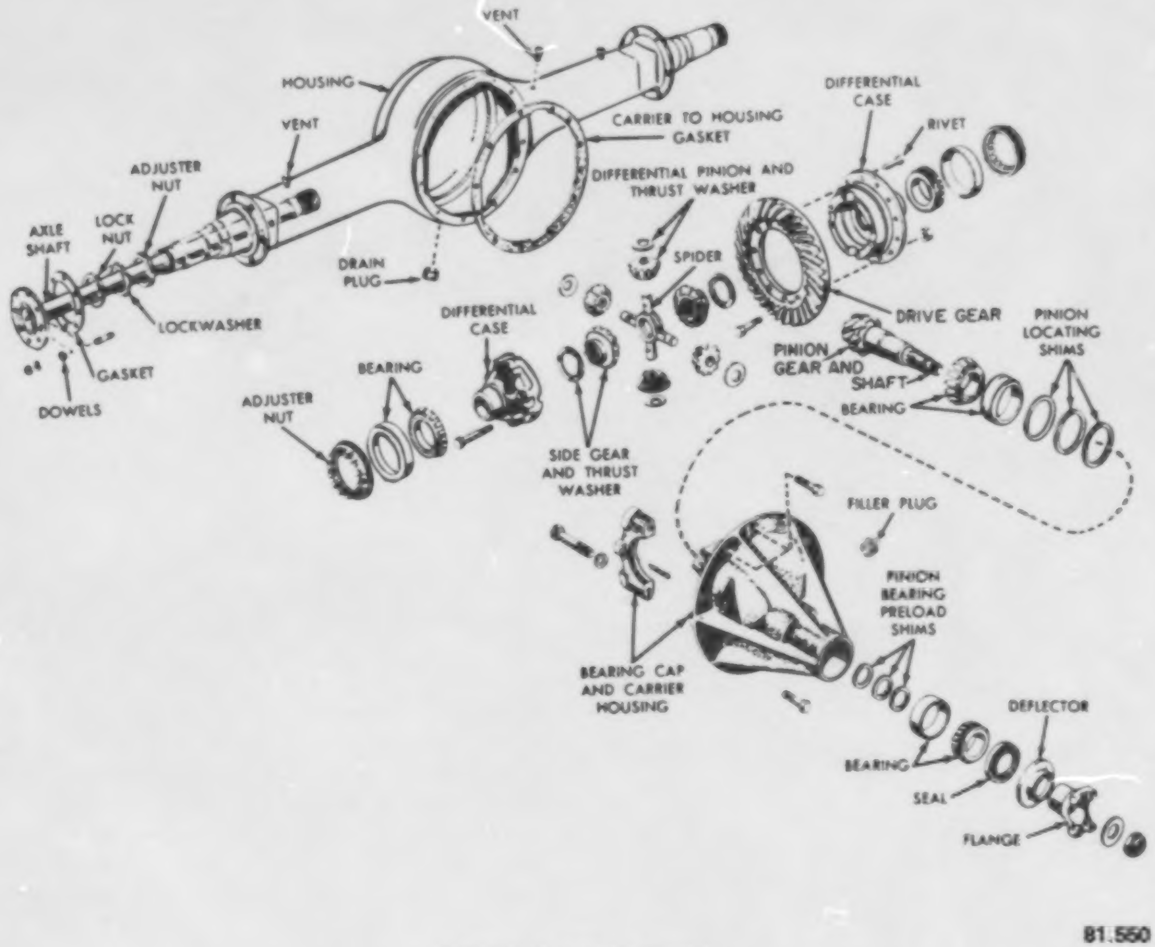
If a noise is present in the differential only when the vehicle is rounding a corner, the trouble is likely to be in the differential case assembly.

When necessary to disassemble the drive axle assembly for repairs, you should jack the vehicle to raise its driving wheels and block the vehicle securely in the raised position. Then use jack STANDS to support the vehicle's weight. DON'T DEPEND ON THE JACK ITSELF TO SUPPORT THIS WEIGHT. Make sure the jack stands are in place and will support the vehicle before getting under a raised vehicle. Unless the axle housing is damaged or must be removed before you can disassemble the drive axle assembly, leave it attached to the vehicle and remove only those parts necessary to complete the required repairs. The axle housing should be thoroughly cleaned and drained before starting the disassembly.

Disassembly

In disassembling the drive axle assembly, remove the axle shafts to allow removal of the differential carrier and gears. The procedure for removing the carrier varies with the different makes of assemblies. On some, the rear cover must be removed before access can be gained; on others, the differential carrier housing is unbolted from the axle assembly housing, as illustrated in figure 8-37.

The carrier should be placed in a stand or on a bench to make your work easier. In some carriers you must mark one of the differential bearing caps and the corresponding carrier leg with a punch. These marks are used when reinstalling the bearing caps. The thread sizes in the right and left bearing caps may be different. If so, the left-hand cap usually has the smaller thread. Remove the bearing caps and carefully remove the differential case and drive gear. If the bearing caps are tight, they can be loosened by tapping them lightly with a soft hammer. Always check the applicable shop manual to determine if certain parts must be match-marked with corresponding parts so that they can be reinstalled in the same relative position. After match-marking, remove the differential case bolts and separate the case. With the case separated, the spider, pinions, side gears, and thrust


VENT
HOUSING
VENT
ADJUSTER NUT
LOCK NUT
AXLE SHAFT
LOCKWASHER
GASKET
DOWELS
DRAIN PLUG
CARRIER TO HOUSING GASKET
DIFFERENTIAL CASE
RIVET
DIFFERENTIAL PINION AND THRUST WASHER
SPIDER
DIFFERENTIAL CASE
BEARING
ADJUSTER NUT
SIDE GEAR AND THRUST WASHER
DRIVE GEAR
PINION GEAR AND SHAFT
BEARING
PINION LOCATING SHIMS
FILLER PLUG
PINION BEARING PRELOAD SHIMS
BEARING CAP AND CARRIER HOUSING
DEFLECTOR
BEARING
SEAL
FLANGE

81.550

Figure 8-37.—Axle assembly.

washers are easily removed. On some assemblies the differential side bearings must be removed with a special puller tool. The tool must be applied so that it grips the inner race of the bearing; otherwise, the bearings will be damaged.

Remove the drive pinion from the carrier housing by removing the flange nut and pressing the shaft out on an arbor press. Remove the bearings from the shaft by using a special remover tool that fits around the shaft and rests on the bearings' inner race while they are being pressed out on an arbor press.

Cleaning and Inspecting

After disassembly of the drive axle assembly, parts should be cleaned with a solvent and brush to remove foreign materials and lubricants. Cleaning the bearings properly is very important. Never clean bearings with gasoline or in a hot solution tank, since this will remove the thin protective lubricant layer. One method of cleaning bearings is to slush them in the cleaning solution until the old lubricant and any foreign materials are washed away.

CAUTION: If you dry the bearings with blasts of compressed air, DO NOT ALLOW THE BEARINGS TO SPIN, since this quickly ruins the bearings. If allowed to spin for just a short time, bearings can gain such momentum that they may suddenly disintegrate showering the entire shop with shrapnel. These small pieces of jagged steel travel at rapid speed and can cause serious injury.

Check the gears for wear on the mating surfaces of the teeth. Use a micrometer to check the thrust washers for wear. When inspecting the bearings, look for pits on the rollers and races. Make sure no small particles of metal are embedded in the bearings, and that the bearings are not excessivley loose in their races. Generally, when overhauling a drive axle assembly, you should replace the bearings if any doubt concerning their condition exists. If the pinion or bevel gear is damaged or shows unusual wear, replacement of both will be necessary as they are machined as a matched set. Should you have any questions while conducting your inspection, see your supervisor or refer to the manufacturer's manual for assistance.

Reassembly and Adjustment

When reassembling the differential carrier, use new shims, spacers, washers, gaskets, and oil seals. Lock all capscrews in place, using either locking strips or soft steel wire. Thoroughly clean the inside of the housing of all grease and oil to make sure that no metal chips or abrasive material is left inside to be circulated by the lubricant.

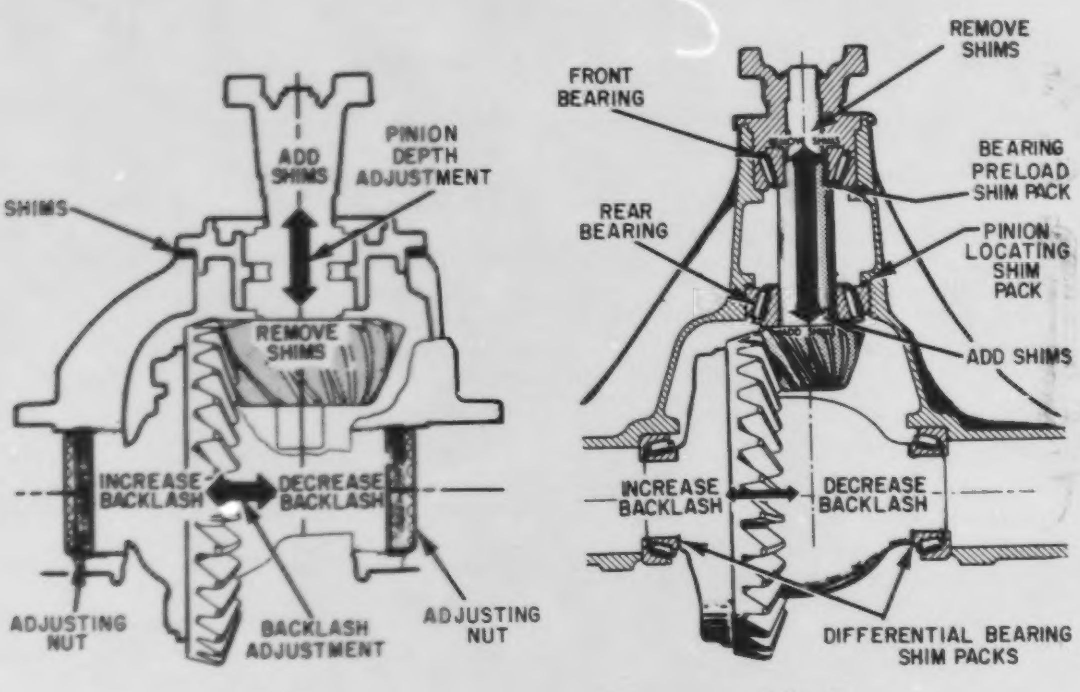
Consult the manufacturer's manual concerning whether or not the bearings are to be preloaded. This manual also describes the method and gages used for adjusting gear tooth contact. The manufacturer's specifications specify the amount of torque to apply to all bolts and nuts. When ball bearings are used, make sure that the thrust side of the bearing is correctly placed to handle side thrust in the proper direction.

A minimum of two adjustments are required which will effect the tooth contact pattern during operation. These are PINION DEPTH and BACKLASH (view A, fig. 8-38). Some units require an additional adjustment called BEARING PRELOAD (view B, fig. 8-38). This adjustment causes the bearings to be positioned in their races exactly as they will be when the vehicle is operating.

The manufacturer's procedures for reassembly and adjustment are very important and should be followed exactly. To do otherwise will result in early failure of the drive assembly after the vehicle is returned to service.

Always adjust the pinion's depth first, then, if required, adjust the pinion's bearing preload. These adjustments are made by adding or removing shims as illustrated in figure 8-38.

Prior to adjusting the backlash, torque the carrier bearing retainers and use a dial indicator (fig. 8-39) to determine the runout (warpage) of the ring gear. If it exceeds the manufacturer's


ADD SHIMS
PINION DEPTH ADJUSTMENT
SHIMS
REMOVE SHIMS
INCREASE BACKLASH
DECREASE BACKLASH
ADJUSTING NUT
BACKLASH ADJUSTMENT
ADJUSTING NUT
REMOVE SHIMS
FRONT BEARING
BEARING PRELOAD SHIM PACK
REAR BEARING
PINION LOCATING SHIM PACK
ADD SHIMS
INCREASE BACKLASH
DECREASE BACKLASH
DIFFERENTIAL BEARING SHIM PACKS

VIEW A

VIEW B

81.551

Figure 8-38.—Pinion and ring gear adjustments.

specifications, the ring gear and pinion must be replaced as a set. If the ring gear is within specifications, locate a position on the ring gear that indicates ONE-HALF of the maximum runout on the gage. Mark the gear at that point. Then rotate the ring gear until the teeth on the opposite side of the gear from the mark are in mesh with the pinion gear.

The backlash adjustment can now be made by adjusting nuts or by moving shims from one side to the other (fig. 8-38). Preload of these bearings is made by adding an additional amount of shims, or tightening the adjusting nuts until a specified amount of effort is required to rotate the differential carrier and ring gear assembly in the housing.

To check the accuracy of your adjustments, coat the ring gear teeth with a thin coat of red lead or Prussian blue and rotate the ring gear. Now observe the tooth contact pattern left on the teeth. By comparison of the pattern with those illustrated in figure 8-40, you can determine if the gears are in correct relationship and if the teeth are making proper contact.

When used gears are properly adjusted, the contact pattern will vary from that of new gears. The important thing to keep in mind with used gears is that the pattern should be closer to the toe than the heel of the tooth as shown in figure 8-40. Notice that the ideal tooth contact pattern on new teeth is uniform on both sides, whereas the used gear indicates considerably more contact on the coasting side.

Once you have obtained the proper adjustment of the ring gear and pinion, bolt the

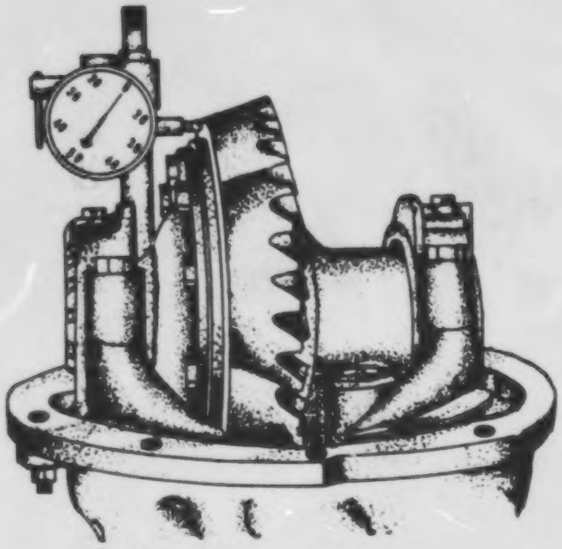


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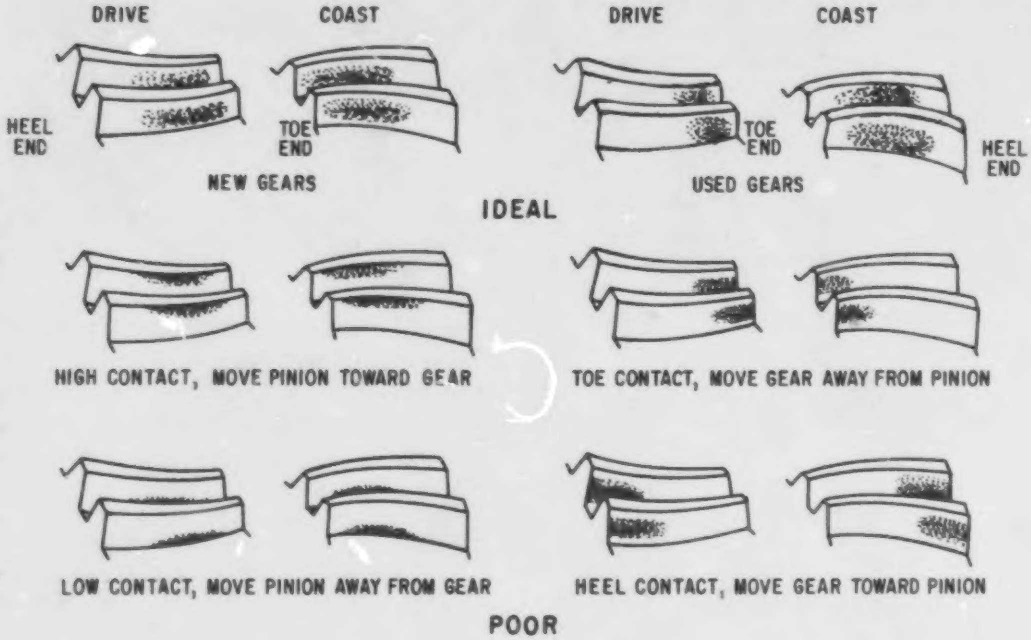
Figure 8-39.—Bevel drive gear runout check.

carrier housing in place using a new gasket. The axle shafts can now be installed with new gaskets. Tighten the bolts according to manufacturer's specifications to prevent their working loose. Reconnect the propeller shaft and fill the axle housing with the proper type and amount of lubricant.

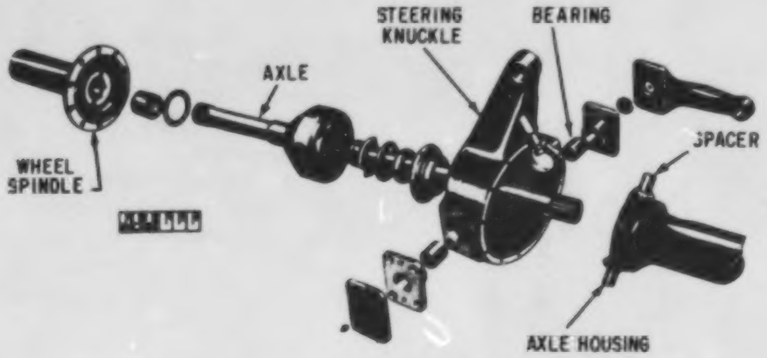
Maintenance procedures for front drive axle assemblies vary from those used in rear drive axle assemblies, in that the axle housing must be partially disassembled in order to remove the axle shafts. This is illustrated in figure 8-41. If worn excessively, a universal joint of the conventional type can be replaced. If the universal joint is of the constant velocity type, like that in figure 8-41, the normal procedure is to replace the complete axle shaft assembly because of the coast and lead time for the individual parts.

When working on vehicles of the military design, 2 1/2-ton and larger, you have to remove the complete axle assembly from the vehicle to remove the differential carrier. These differential


DRIVE
COAST
HEEL END
TOE END
NEW GEARS
DRIVE
COAST
TOE END
HEEL END
USED GEARS
IDEAL
HIGH CONTACT, MOVE PINION TOWARD GEAR
TOE CONTACT, MOVE GEAR AWAY FROM PINION
LOW CONTACT, MOVE PINION AWAY FROM GEAR
HEEL CONTACT, MOVE GEAR TOWARD PINION
POOR

81.563

Figure 8-40.—Tooth contact patterns.



81.554

Figure 8-41.—Partial view of front axle assembly.

assemblies are the same on the front or rear driving axles and are interchangeable.

Should you disassemble the front axle assembly, it will be necessary to insure proper adjustment of the steering knuckle supports. The proper clearance is provided for by the use of shims (fig. 8-35) or a spacer (fig. 8-41). Different methods are used to determine if the adjustment is correct. Some require the use of a spring scale to measure the effort required to turn the steering knuckle. Others depend on actual measurement of the clearance with the use of a thickness gage or a dial indicator. Regardless of the method used, this adjustment is critical to the steering of the vehicle. Castor and camber on trucks with front drive axles are not adjustable because these steering factors are built into the axle assembly. If too tight, hard steering will result. If too loose, shimmy and lack of vehicle control by the operator will result.

AUTOMOTIVE WINCHES

Automotive winches that you will encounter are used on tactical (military) vehicles. These winches obtain power from the power takeoff by a solid drive shaft and universal joints. The universal joint yoke connected to the worm shaft of the winch has provisions for a shear pin that is made of mild steel. This pin has a predetermined breaking (shearing) strength that allows it to shear when the winch is overloaded. An automatic brake holds the drum from turning when no power is applied. A lever on the winch is used to engage or disengage the drum from the drum shaft and allow free wheeling of the drum.

Faulty operation of winches is usually caused by a broken shear pin. Internal damage of the winch can be caused by use of a shear pin that has too high a breaking strength. Internal winch failure resulting from overload is commonly found to be sheared keys or a broken worm shaft. Often, when the cable is wound unevenly under tension, the winch housing will be cracked or broken. This will require replacement of the assembly.

When performing maintenance on a winch, insure that the gear case has the recommended type and amount of lubricant. NEVER INSTALL A SHEAR PIN THAT IS NOT OF THE PROPER TYPE. Should you disassemble a winch for repairs, do so by following the procedures given in the manufacturer's maintenance manual.

CHAPTER 9

AUTOMOTIVE CHASSIS AND BODIES

The automotive chassis provides the strength necessary to support the vehicular components and the payload placed upon it. The suspension system contains the springs, shock absorbers, tires, and wheels that allow the vehicle to pass over uneven terrain without an excessive amount of shock reaching the passengers or cargo. The steering mechanism is an integral portion of the chassis and suspension. It provides the operator with a means of controlling the direction of travel. The body or outer portion of the vehicle encloses the mechanical parts and passenger compartment. It is made of relatively light sheet metal. The components which make up the chassis of the vehicle are held together in proper relation to each other by the frame.

THE FRAME

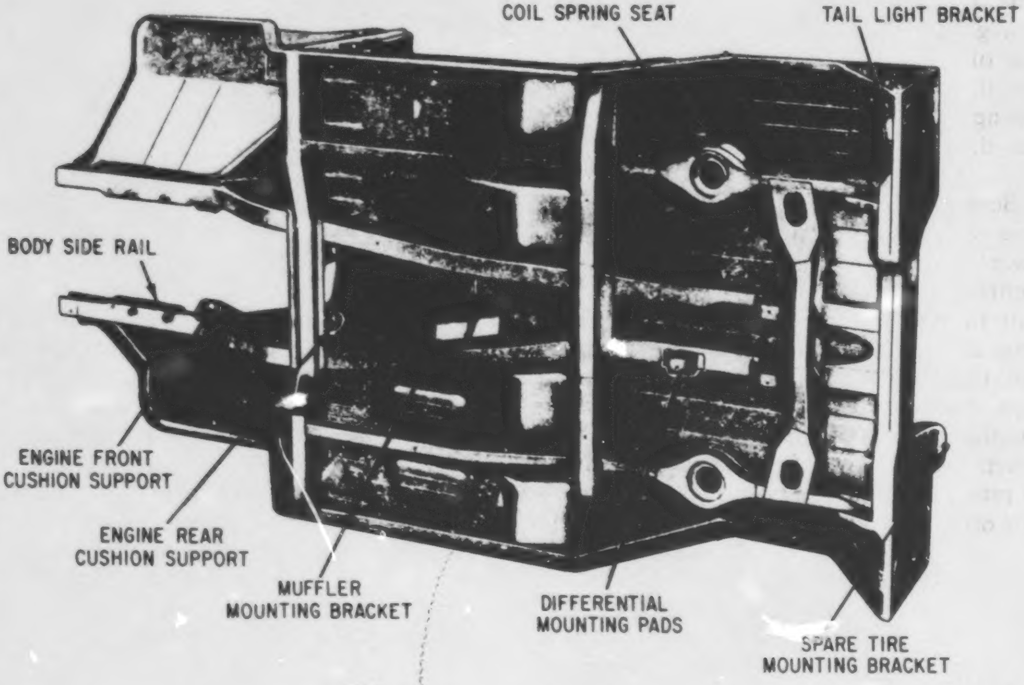
Vehicular frames are made in numerous shapes and sizes. The major factors used in determining the type of frame are the size of the vehicle and the weight that it will carry.

Vehicles that have a short wheel base (110" or less) and carry light loads may not have a frame. In place of a frame, the body is reinforced at critical points to allow attachment of the power train, suspension, and steering mechanisms. Figure 9-1 illustrates such a body that is used on the military jeep. Other vehicles may have only a short section of frame welded to the front and rear portions of the body for mounting the suspension, steering and/or the engine and transmission. This type of vehicle construction is permitted with unitized bodies, where the body and frame are welded into one piece.

The full size automotive vehicle has a frame similar to the one illustrated in figure 9-2. This type of frame may be constructed of cold-rolled steel or an alloy to lighten the weight of the vehicle. The SIDE MEMBERS or RAILS are the heaviest parts of the frame. The CROSS MEMBERS are fixed to the side members strongly enough to prevent weaving and twisting of the frame. Additional reinforcement of these connections is provided on heavy-duty truck frames by the use of angular pieces of metal called GUSSET PLATES.

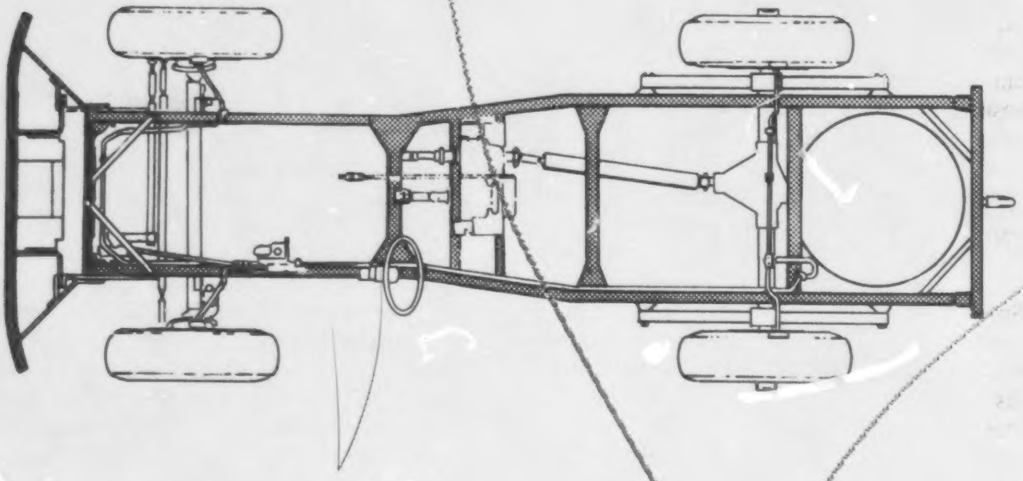
The number, size, and arrangement of cross members depend on the type of vehicle for which the frame is designed. Usually, a front cross member supports the radiator and front end of the engine as well as stiffens the frame. The rear cross members furnish support for the fuel tanks and rear trunk on passenger cars, and the tow-bar connections for trucks. Additional cross members are added to the frame to support the rear of the engine or power train components and to secure the rigidity required.

The cross members of most small vehicles are designed in either X or K form. The front cross members are wider and of heavier construction than the back members because they support the engine and the front wheels. The side members are shaped to accommodate the body and support its weight. They narrow toward the front of the vehicle to permit a shorter turning radius for the wheels and widen under the main part of the body where the body is secured to the frame. Trucks and trailers usually have frames with straight side members to accommodate several designs of bodies and to give the vehicle added strength to withstand heavier loads.


COIL SPRING SEAT
TAIL LIGHT BRACKET
BODY SIDE RAIL
ENGINE FRONT CUSHION SUPPORT
ENGINE REAR CUSHION SUPPORT
MUFFLER MOUNTING BRACKET
DIFFERENTIAL MOUNTING PADS
SPARE TIRE MOUNTING BRACKET

81.555

Figure 9-1.—Unitized body and frame.



81.556

Figure 9-2.—Typical frame design used on light trucks.

Brackets and hangers bolted or riveted to the frame support the shock absorbers, fenders, running boards and springs. These are usually made of case or pressed steel, depending on the strength required. Spring hangers, subject to twisting and running gear stresses are, in most cases, drop forgings.

Bumpers are attached to both ends of the frame side rails by bolts and braces or plates. Newer automobiles have bumpers that are mounted in such a manner that no damage will result to the vehicle if involved in a collision at speeds of five miles per hour or less if the impact is in the straight ahead or reverse direction. These bumpers are made to retract against cushioning devices that absorb the force of the impact. With some of these designs, the bumper will return automatically to its original position while others must be manually readjusted.

SUSPENSION SYSTEMS

The suspension system has been mentioned in the previous chapter covering drive lines and axles, but only as related to thrust and ways of transmitting it to the frame. The suspension system on a vehicle is also used to support its weight, provide for the absorption of road shock, and to permit even and controllable steering. The components of the suspension system that are common to most general purpose vehicles are the axles (previously described), springs, shock absorbers, wheels, and tires.

SPRINGS

Springs support the frame and the body of the vehicle, as well as the load the vehicle carries. They allow the wheels to withstand the shocks of uneven road surfaces and provide a flexible connection between the wheels and the body. Extremely flexible or soft springs allow too much movement of the vehicle, while stiff, hard springs do not allow enough movement.

The springs do not support the weight of the wheels, rims, tires, and axles. These parts make up the unsprung weight of the vehicle. The unsprung weight decreases the action of the springs and is, therefore, kept to a minimum to permit a smoother ride.

Several types of springs have been devised, the most common of which are the leaf (laminated), coil, and the torsion bar. Although the design of each is different, the purpose they serve is the same. They are used to cushion the shock that results from passing over uneven surfaces (road shock).

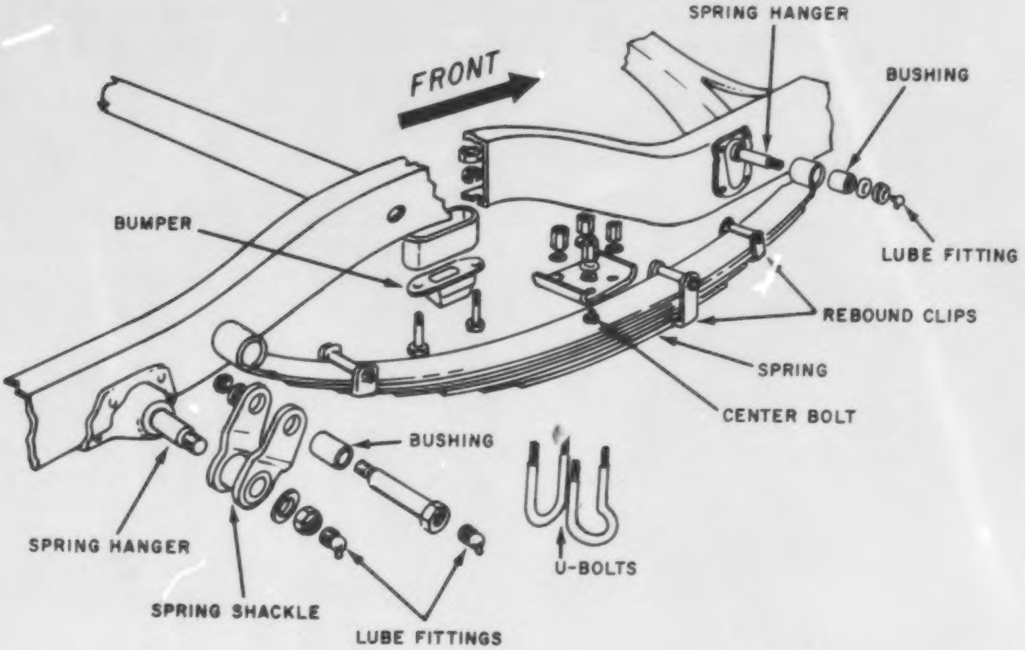
Leaf Springs

Springs made of leaf design are found in use with one or more leaves. The single leaf is restricted to use with small vehicles that do not carry any appreciable load and are relatively light in construction.

The type you will commonly encounter on Navy equipment is the multiple leaf or laminated spring shown in figure 9-3. It consists of a number of steel strips or leaves of different lengths, fastened together by a bolt through the center. Each end of the largest master leaf is rolled into any eye which serves as a means of attaching the spring to the spring hanger and spring shackle. Rebound clips surround the leaves at two or more intervals along the spring to keep them from separating on the rebound after the spring has been depressed. The clips allow the spring leaves to slide, but prevent them from separating and causing the entire rebound stress to act on the master leaf. The leaf spring acts as a flexible beam, on self propelled vehicles, and transmits the driving and breaking forces to the frame from the axle assembly.

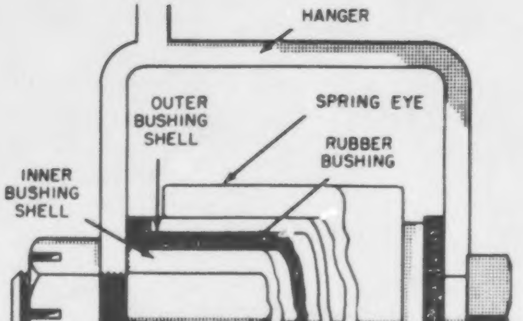
Leaf springs are mounted in a lengthwise position on the self-propelled vehicles and sometimes transversely (crosswise) on trailer mounted equipment. In trucks and cars the rear springs may be clamped under the axle to lower the center of gravity. A low center of gravity will help prevent a heavily loaded truck from upsetting.

When installed lengthwise, both ends of the springs are attached to the frame and the center


SPRING HANGER
FRONT
BUSHING
BUMPER
LUBE FITTING
REBOUND CLIPS
SPRING
CENTER BOLT
BUSHING
SPRING HANGER
U-BOLTS
SPRING SHACKLE
LUBE FITTINGS

81.557

Figure 9-3.—Multiple leaf spring.


HANGER
OUTER BUSHING SHELL
SPRING EYE
RUBBER BUSHING
INNER BUSHING SHELL
RUBBER WASHER
SPRING BOLT

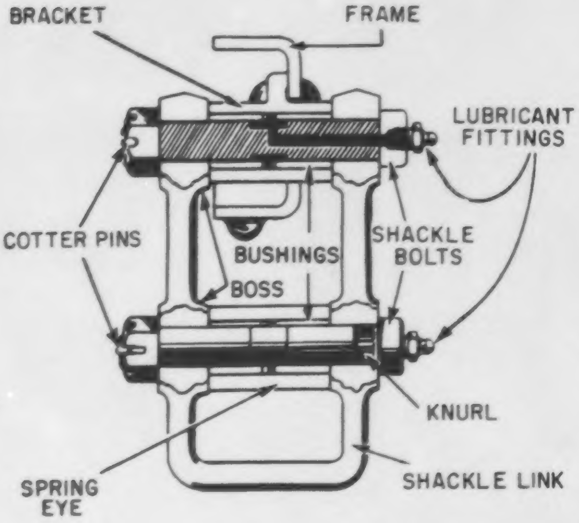
81.558

Figure 9-4.—Spring hanger.

is clamped to the axle or spring seat. The forward end of the spring is connected by a pin or bolt, directly to a spring hanger (fig. 9-4), permanently attached to the frame. A spring shackle (fig. 9-5) is used as a connecting link between the rear of the spring and the hanger. The bushings and pins provide the bearing or support points for the vehicle.

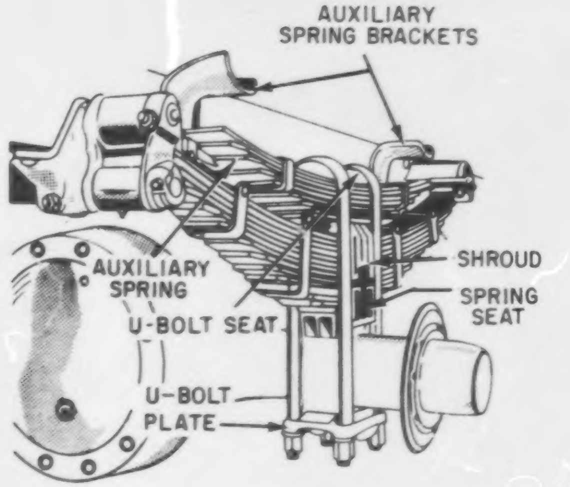
Spring bushings may be made of bronze or rubber, and are pressed or threaded into the spring eye. The steel bolts or pins that pass through the bushing are either plain or threaded. The threaded bushing and shackle bolts offer a greater bearing surface and are equipped with lubrication fittings.

Leaf springs are used front and rear on heavy-duty trucks, and the rear of some automobiles and light trucks. Trucks that carry a wide variety of loads, use an auxiliary or overload spring. This spring (fig. 9-6) may be



81.559

Figure 9-5.–Spring shackle.



81.560

Figure 9-6.–Auxiliary spring.

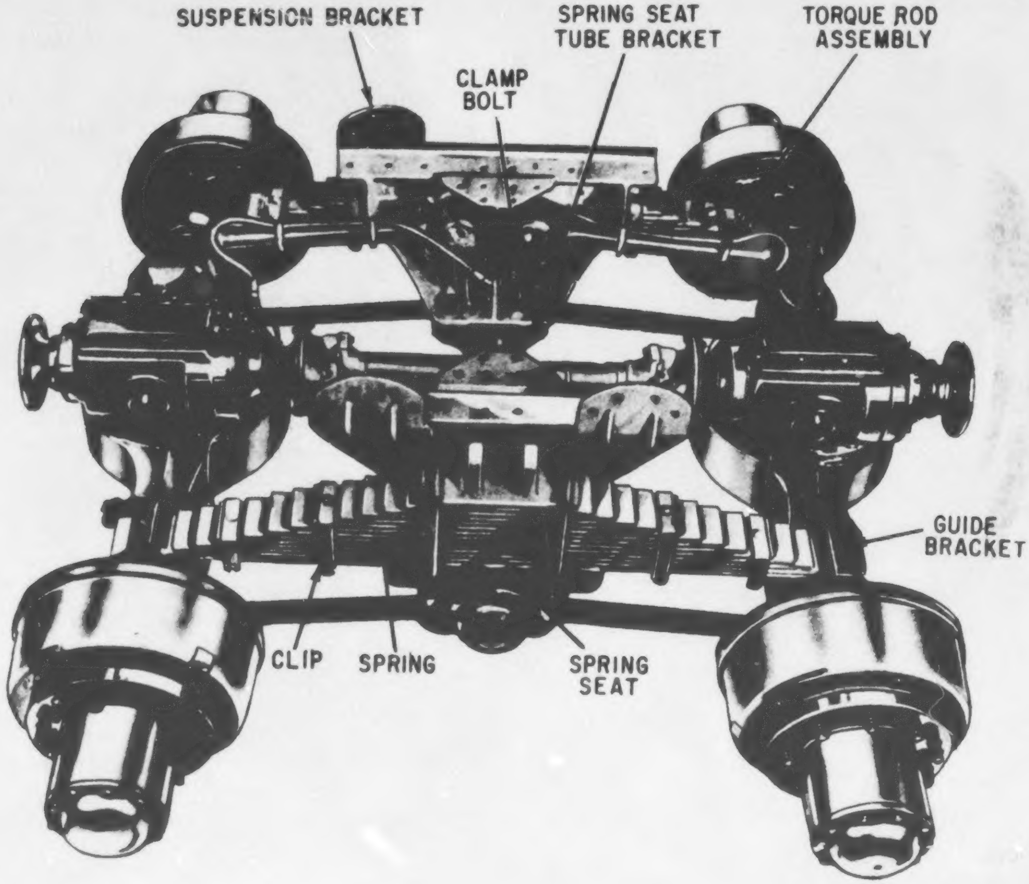
mounted on top of the rear springs and clamped together with long U-bolts, or it may be located under the axle separate from the main spring. In either case, the ends of the spring have their own support brackets. When the truck is under load, the auxiliary spring assumes part of the load when its ends contact the bearing plates or special brackets attached to the frame siderails.

Some general-purpose trucks of the six-wheeled design use a bogie suspension for the rear wheels. This suspension (fig. 9-7) is a unit consisting of two axles joined by torque rods. The cross-shaft (tube) acts as a pivot for the drive axles and is supported by bearings that are part of the spring seat. The ends of each spring rest in guide brackets bolted to the axle housings. Mounting the springs on central pivots enables them to distribute half of the rear load onto each axle. As a result, this type of suspension allows the vehicle to carry a much heavier load than the single axle vehicle without losing its ability to move over unimproved terrain.

When one wheel of a bogie suspension is moved up or down because of an irregularity in the road, the spring pivots on the cross shaft and both ends of the spring deflect to absorb the road shock. This causes the load to be placed on the center of the spring resulting in equal distribution of the load to both axles. The torque rods insure proper spacing and alinement of the axles and transmit the driving and braking forces to the frame.

Coil Springs

When the wheel at either end of a solid axle receives a shock, the whole suspension for the axle is affected. This means that the unspring weight is set in motion, tending to result in poor riding qualities. This is the reason that the unsprung weight should be kept to a minimum. To help reach this objective, manufacturers introduced independent suspension, which allows each wheel to move independently of the remainder of the vehicle. The use of independent suspension created a different requirement for spring mounting and resulted in the use of coil springs. The coil spring is made of a single steel piece bent into a coil. This spring is more flexible than the leaf spring, allowing a smoother reaction when passing over irregularities in the road. Because of its design, the coil spring cannot be used for torque

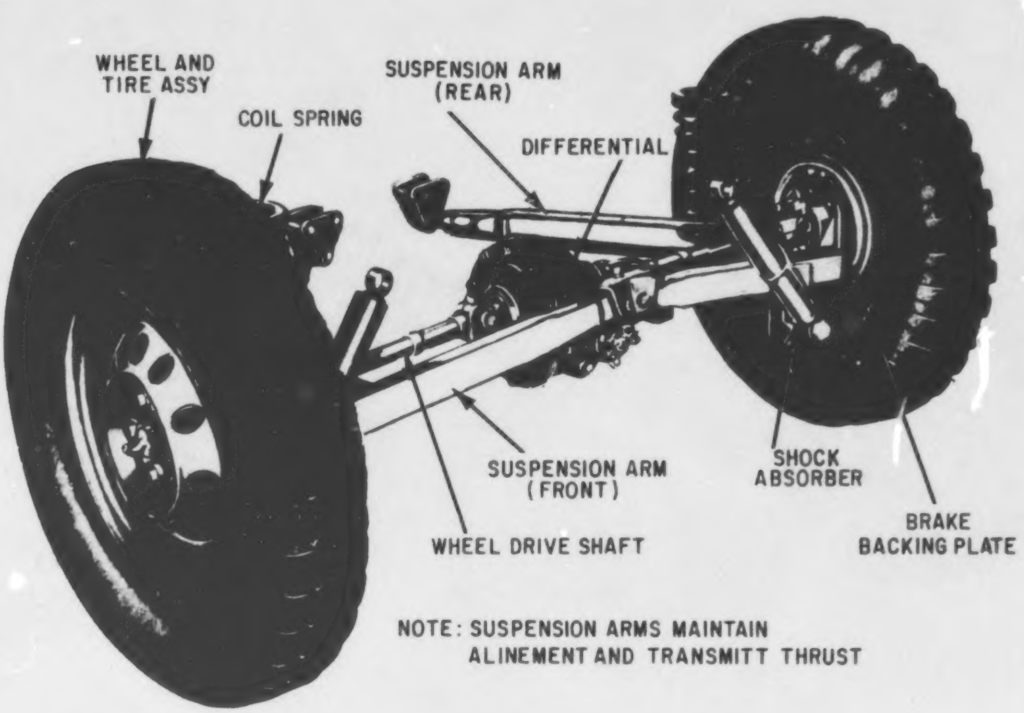


81.561

Figure 9-7.—Bogie suspension system.

reaction or absorbing side thrust. Consequently, the coil spring must be used with suitable torque members that will take up these thrusts and hold the axle in alinement (fig. 9-8).

Coil spring mountings are quite simple in construction. The hanger and spring seat are shaped to fit the coil ends and hold the spring in place. Cups, which fit snugly on each coil end, are often used for mounting a coil spring. The upper cup may be formed within the frame (fig. 9-1), in the control arms, or it may be a part of a bracket rigidly fixed to the crossmember or frame rail (fig. 9-9). The lower cup is fastened to a control arm hinged to a crossmember or frame rail. Rubber bumpers are included in the lower spring support to prevent metal-to-metal contact between the frame and arm as the limits of compression are reached. A stabilizer bar is used to connect the two lower control arms for the purpose of preventing too great a difference in spring action. This member also tends to keep the wheels in alinement, resulting in better steering ability and riding comfort. When operating a vehicle on a curve, the centrifugal force tends to compress the outside coil spring with an expansion of the inner one. The stabilizer bar is acted on by this twisting force,


WHEEL AND TIRE ASSY
COIL SPRING
SUSPENSION ARM (REAR)
DIFFERENTIAL
SUSPENSION ARM (FRONT)
WHEEL DRIVE SHAFT
SHOCK ABSORBER
BRAKE BACKING PLATE
NOTE: SUSPENSION ARMS MAINTAIN ALINEMENT AND TRANSMITT THRUST

81.562

Figure 9-8.—Shock absorber in a jeep rear suspension.

but because of its resistance, the bar attempts to equalize the spring length and reduce the tendency for body roll.

Torsion-bar

Some passenger cars and light trucks use torsion bars as springs to return the front wheels of a vehicle to their original position with respect to the vehicle frame. The torsion bar, made of spring steel, is connected to one of the control arms (normally the lower) at the front of the vehicle and to a crossmember or special bracket connected to the vehicle frame. The bar is twisted laterally by the weight of the vehicle and the upward or downward motion of the control arm when the wheel passes over uneven surfaces. An adjustment is provided at one end of the bar to preload the bar (spring) and control the riding height of the front of the vehicle.

SHOCK ABSORBERS

The main function of a shock absorber (fig. 9-8 and 9-9) is to regulate the spring rebound so that the spring returns to rest slowly, preventing sudden jolts and bounces from being transmitted to the vehicle body and its occupants and cargo. Shock absorbers which check only the spring rebound are known as single-acting. A shock absorber may also dampen the compression of the spring by absorbing part of the energy as the spring is depressed. Shock absorbers which check compression in addition to rebound are known as double-acting. Most shock absorbers used at the present time are the double-acting, direct-action type, because they permit the use of more flexible springs.

Shock absorbers are mounted on studs and bushings in such a manner that spring movement acts directly on them. The shock absorber

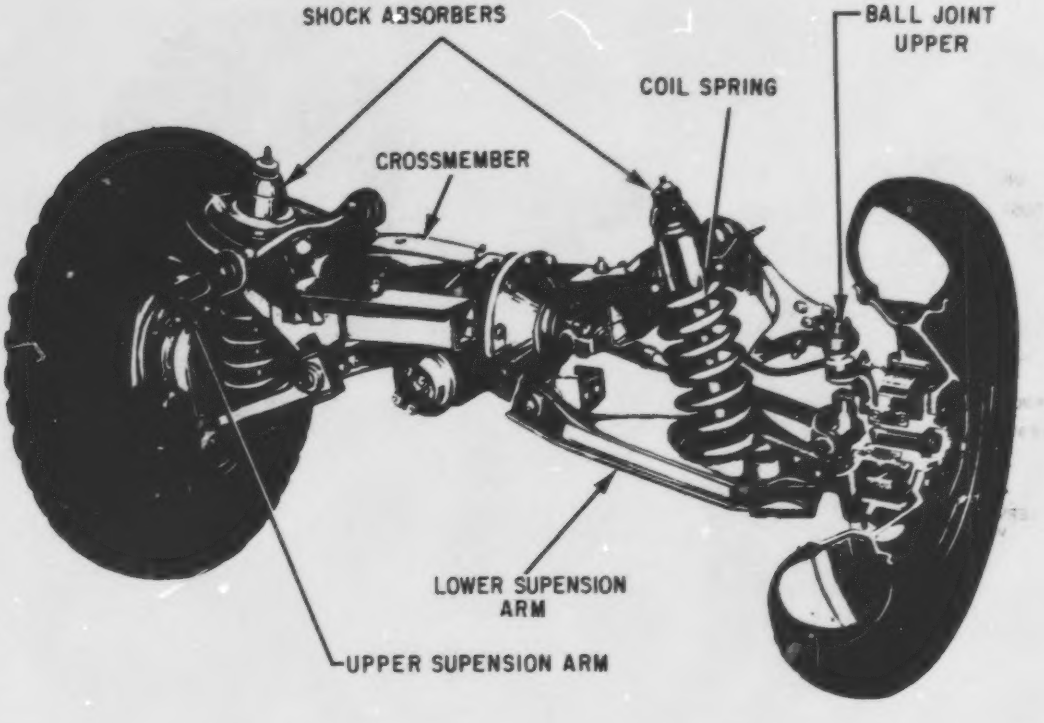


Figure 9-9.—Shock absorber in a jeep front suspension.

depends on valve action to restrict oil flow within itself and thus control the compression or rebound of the springs. (See fig. 9-10.) Shock absorbers are hydraulically operated and depend upon the resistance of a liquid (oil) flowing through a restricted opening. Oil contained within a housing is forced through the restricted opening by a piston when the vehicle springs flex. Since liquids are not compressible under ordinary pressures, the oil takes a certain time to flow through the restricted opening. The rate of piston travel, which controls the period of spring flexing, is determined by the opening through which the oil must flow.

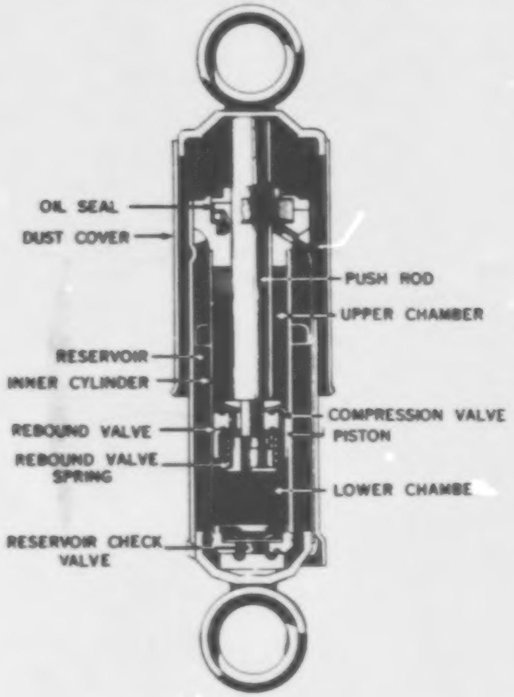
SPRING, SHOCK ABSORBER, AND FRAME MAINTENANCE

Overloading, sudden stops or starts, and wheels running into holes or obstructions are the major causes of broken springs. Speed changes and bounces cause the load to shift suddenly, placing all the strain on a single spring.

Springs that have taken jars and jolts over a long period are more likely to break than new springs. The spring leaves lose their tension and the shackles and pins become worn.

Under normal operation and the proper maintenance, springs will not need replacing for many miles. Some of the common points that should be regularly checked on spring assemblies are as follows. Insure that all shackles are tight and that the bushings within the shackles are not worn excessively or frozen tight. Insure that the U-bolts are tight, so as to prevent shifting of the spring assembly. Replace any broken leaf clips on the spring assembly.

Springs are lubricated at regular intervals, and it is your job to see that grease gets through the grease fitting to both sides of the shackles. Grease on the outside of the shackles is wasted;



81.564

Figure 9-10.–Sectional view of direct-acting shock absorber.

it must be forced between the shackle bolts and spring bushings to reduce friction.

Use a bar, or jack up the body if necessary, to loosen the bearing surface. If the grease gun forces grease out of the fitting instead of through the shackle bolt, the grease fitting must be replaced. It is often necessary to use a wire to remove caked grease from the openings.

Both surfaces of spring leaves are lubricated with a film of grease before the spring is assembled. In passenger cars, it is a good practice to occasionally spray the spring leaves. Lubricating oil sprayed on springs will prevent squeaking at the ends of the spring leaves as they move slightly when the springs are flexed.

Shock absorbers are of the telescoping or airplane type and no means is provided for repairing.

In replacing shock absorbers it is better to replace both absorbers AS A PAIR, even if but one is defective, in order to keep the riding equilibrium of the vehicle.

When a bushing becomes worn, it is best to replace the bushing on EACH pair of shock absorbers at the same time.

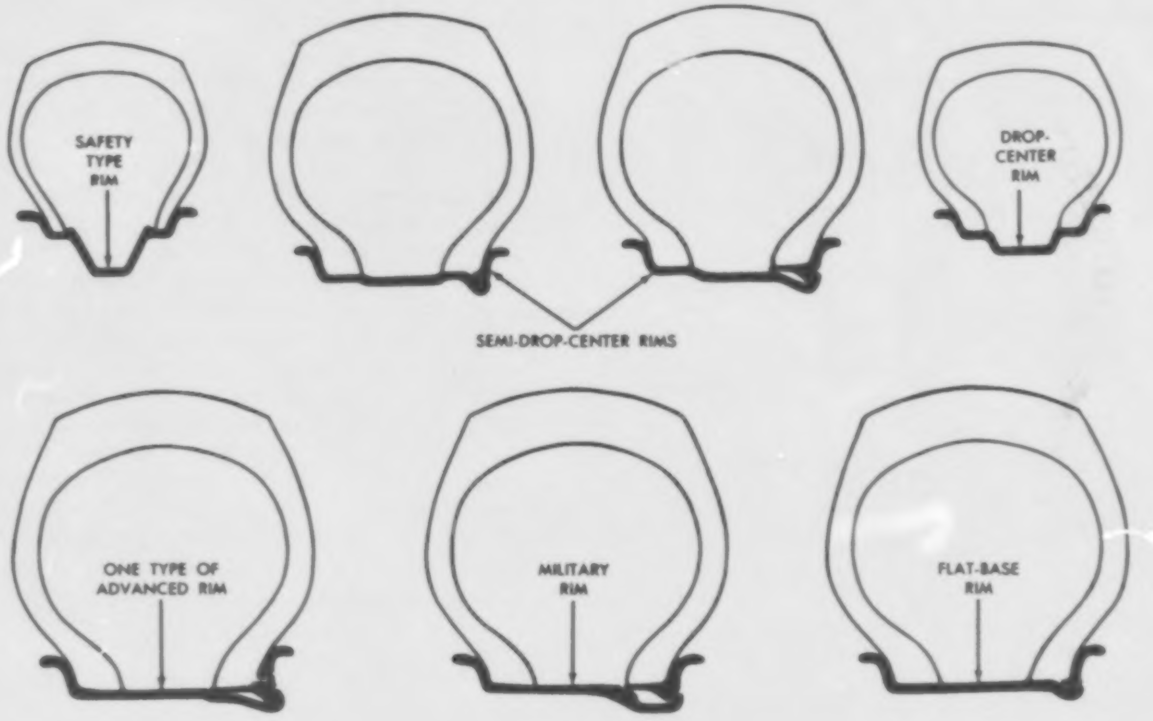
Frames require little, if any maintenance. However, if the frame is bent enough to cause misalinement of the vehicle or cause faulty steering, the vehicle should be removed from service. Small cracks or brakes in the frame side members can be temporarily repaired by drilling the frame and fishplating. Care should be exercised when performing this task as the frame may be weakened. The frame of a vehicle should not be welded by gas or arc welding unless specified by the manufacturer. The heat may remove the temper from the metal, and if cooled too quickly, causes the metal to crystallize. Minor bends can be removed by the use of hydraulic jacks, bars, and clamps.

WHEELS AND RIMS

Wheels must have enough strength to carry the weight of the vehicle and withstand a wide range of speed and road conditions. Automobiles and light trucks (usually 1/2-ton or less) are equipped with a single piece wheel and rim. Small military vehicle rims and wheels are the single-piece design (wheel and rim in a single unit). The larger capacity ones, 1 1/4 ton or more, have a lockring (side ring) that allows easy removal of the tire from the rim and, when in place, provides a seat for one side of the inflated tire.

Rim designs (fig. 9-11) that are common to military vehicles are the SAFETY, SEMIDROP CENTER, and the MILITARY.

The identification of the military vehicle is partly determined by the amount and use of the wheels. If it has two axles, there are four wheels. The automobile has four wheels, but only two drive the vehicle. Thus, the automobile is designated as a 4 x 2. The jeep is a 4 x 4,



81.248

Figure 9-11.—Types of rims.

because it can be powered by all four wheels. Six-wheel vehicles can be 6 x 4 or 6 x 6, depending on the number of drive axles. Duel tires are considered as one wheel for purposes of vehicle designations.

TIRES

Tires are designed and manufactured for use under two general operating conditions, over the road at highway speeds and off the road at speeds less than 30 miles per hour.

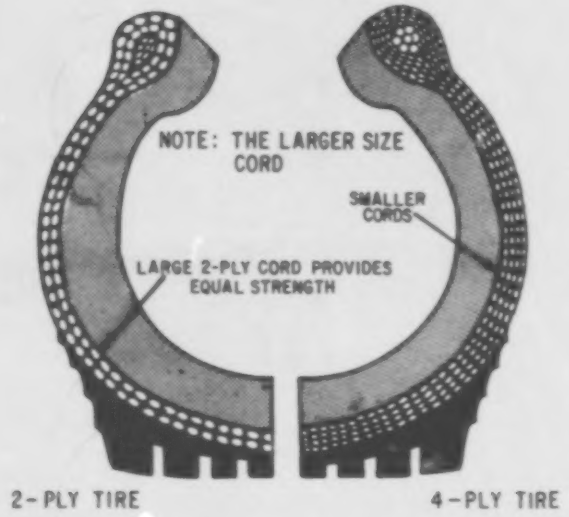
Tires designed for use at highway speeds must be able to withstand the constant flexing caused by irregularities in the road surface. Flexing results in heat that will cause early failure of the tire.

Slow speed or off-the-road tires have no problem with heat because of the relatively slow speed at which they travel. The major concern with these tires is strength to withstand the heavy loads and shock from contact with uneven terrain or sharp objects.

To satisfy the two kinds of operating requirements, tires are available in different sizes, plies, profiles, and tread designs. You may encounter some truck tires that contain a combination of features allowing them to be used under conditions of both high and low speeds.

TIRE CONSTRUCTION

The modern tire (fig. 9-12) consists of a number of plies (layers of cord material coated with rubber) that surround the bead and are bonded together with rubber. The tread portion


NOTE: THE LARGER SIZE CORD
SMALLER CORDS
LARGE 2-PLY CORD PROVIDES EQUAL STRENGTH
2-PLY TIRE
4-PLY TIRE

81.565
Figure 9-12.–Comparison of 2- and 4-ply tires.

consists of additional rubber added to the carcass and molded, during the curing process, into a special shape or design. The tread is needed to provide traction or mileage, or a combination of both, depending on the intended use of the tire. The bead portion of the tire gives strength to the sidewall where it is attached to the rim and prevents separation of the tire and rim during use.

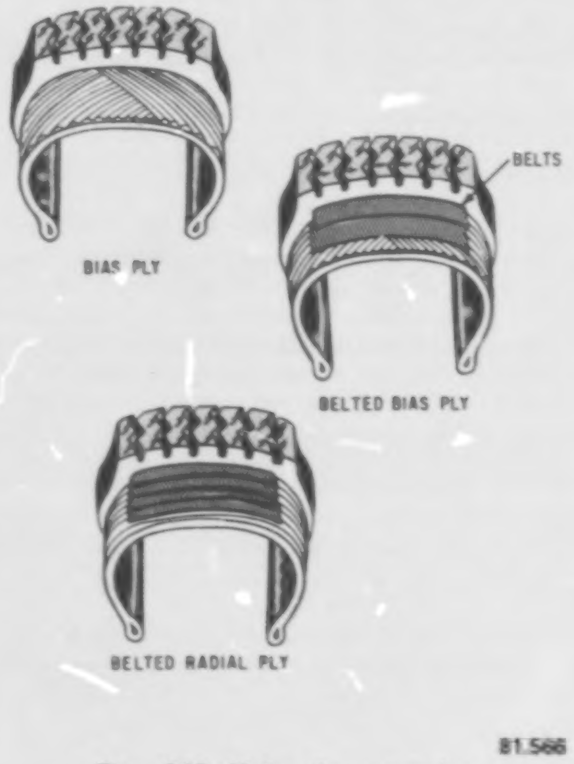
The strength of a tire is determined by the number, arrangement, and type of material used in the plies. Figure 9-13 illustrates the three methods of tire construction used today. The most common ply used on military vehicles is the bias ply. This means that the plies lie at an angle to the bead and each ply is placed 90° in relation to the previous one. Two or more plies are used depending on the strength of the tire.

The bias belted tire contains two or more layers of fabric under the tread. This fabric or BELT provides additional strength to the tread portion of the tire.

The radial tire has the sidewalls constructed with the plies at a 90° angle to the bead. This causes the sidewall to be much more flexible than the other designs. For that reason, the radial ply tire may look half flat when actually fully inflated.

The material used for the strength members in a tire are varied. Sidewalls may consist of nylon, rayon, or polyester. Polyester is not affected by water, nor does it have flat spots when cold. Nylon is preferred for its strength and resiliency but has the fault of the flat spot on cool mornings or when the vehicle has sat in one spot for a length of time. Rayon, which has been used the longest, has the disadvantage of deteriorating when exposed to moisture for periods of time.

The belts used on belted tires are made of fiberglass, steel or rayon. The steel provides the greatest tread strength, and the longest mileage for a given thickness of tread. Fiberglass allows more flexing than the steel and results in



81.566
Figure 9-13.–Modern tire construction.

reduced mileage. Rayon belts are compatible with the flexing and heat buildup and provide about the same mileage as the fiberglass belts.

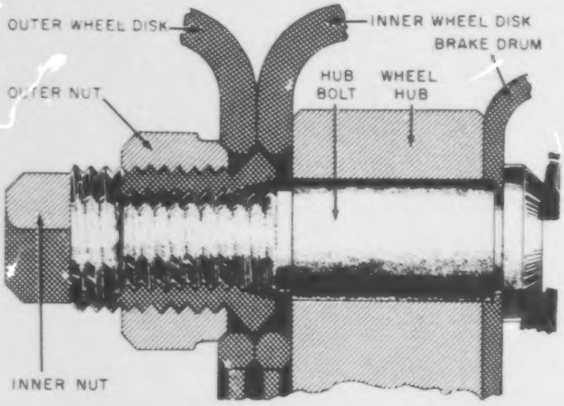
TIRE MARKINGS

Manufacturers permanently mold data into the sidewall of a tire. This information includes tire size, inflation pressure, manufacturer's name and code number and the type of material used in the cord. Other information may include the number of plies (sidewall and tread), whether "tube" or "tubeless," design and DOT, indicating that is meets federal Department of Transportation safety standards.

CHANGING THE TIRE AND WHEEL

Prior to removing the tire from a vehicle, insure that the emergency brake is locked, the transmission lever is in PARK, FIRST or REVERSE depending on the type of transmission. Locate something suitable for blocking the wheels to prevent the vehicle from rolling as you raise it with the jack. Never block the wheels on an axle you are raising with the jack.

For automobiles and light trucks, remove the hub cap if so equipped and using the lug wrench or a suitable substitute, slightly loosen the bolts or nuts that hold the wheel to the hub. Now raise the wheel with the jack, observing the vehicle to insure that it does not roll while being raised. If the vehicle attempts to roll, lower the jack and add additional blocking to the wheels. This should eliminate any problem of rolling while raising the vehicle. After the wheel is clear of the ground approximately 1 inch, finish removing the lug nuts or bolts and remove the wheel from the vehicle. **DO NOT LEAVE THE VEHICLE SUSPENDED ON THE JACK.** If work is to be done to the vehicle while the tire is removed, place an approved safety stand and or suitable blocks under the axle to hold the vehicle. If the jack is not located on firm material, the weight of the vehicle can cause it to settle and allow the vehicle to shift and fall. If no other work is expected to be done, install the spare tire as soon as possible to prevent damage to the vehicle or personnel.

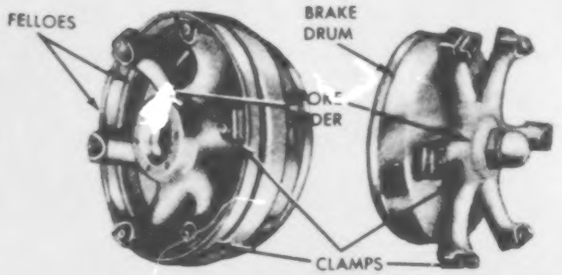


29.111

Figure 9-14.—Dual disk wheel mounting.

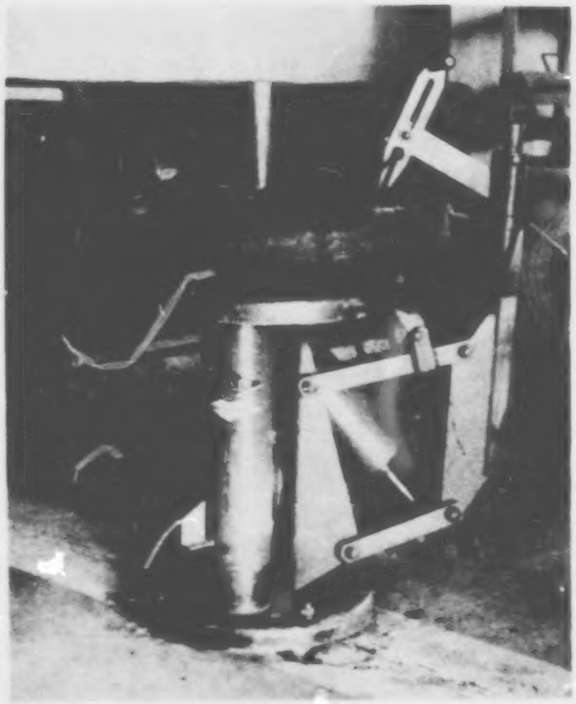
Removing dual disk wheels to change tires on heavy vehicles is not too difficult. Generally, both disks are fastened together by two nuts on each hub bolt—one nut for each wheel. Either single or dual wheels can be securely mounted on the same hub with this arrangement. Outer nuts must be loosened first, freeing the outer wheel disk from the hub. Loosening the outer nuts, which thread over the inner nuts, unfastens the outer wheel disk. In removing dual disk wheels you will find left-hand threads on both inner and outer nuts on the left wheels and right-hand threads on those of the right wheels. The dual wheel mounting is illustrated in figure 9-14. Reverse the procedure to mount and tighten the wheels.

On trucks having spoke wheels, the tire and tube are removed with the rim. After removing the clamps which secure the rim on the spoke spider (fig. 9-15), the rim with the tire and tube can be lifted off. If the spoke wheel has two rims and tires, the second rim and tire can be lifted off after the spacer separating the rims is removed. When replacing the wheels, install the outer dual so that the valve stem will be 180° from the stem on the inner tires. This will help the operator to locate the inner [illegible] for periodic checking and inflation.



29.112

Figure 9-15.–Truck spoke wheels.

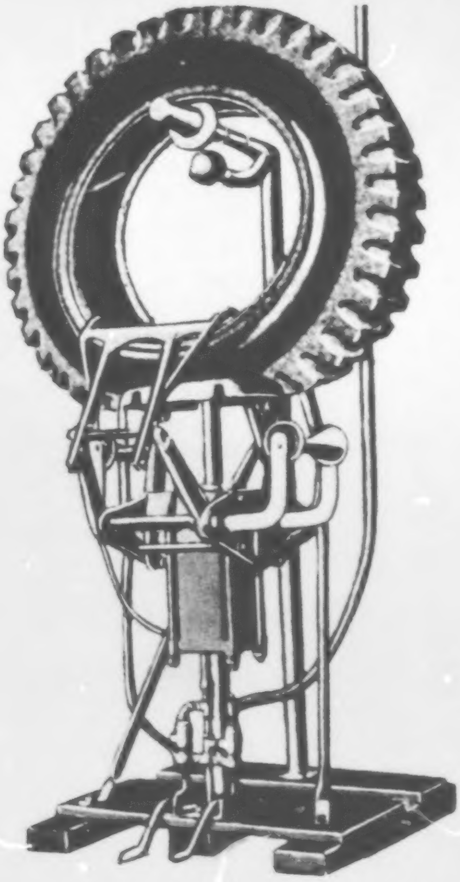


81.22

Figure 9-16.–Pneumatic tire demounter.

TIRE REMOVAL AND REPLACEMENT (TUBE TYPE)

Facilities for repairing tires will vary from one location to another. Permanent locations have some essential power operated tire repair equipment that may be similar to those illustrated in figures 9-16 and 9-17.



81.23

Figure 9-17.–Pneumatic tire spreader.

Working in the tire repair shop is a dirty and sometimes difficult job. However, with the right tools and a little experience, this task will be no more difficult than other assignments in the maintenance shop.

The demounter (fig. 9-16) is used to break the tire bead loose from the wheel rim. The wheel and tire can be mounted on the demounter so they will not turn. An adapter can then be used that will remove the tire from or replace it onto the rim. Tire demounters may be either manual, hydraulic, or air operated. The one shown in figure 9-16 is an air operated demounter. This type is used for automotive and light truck tires.

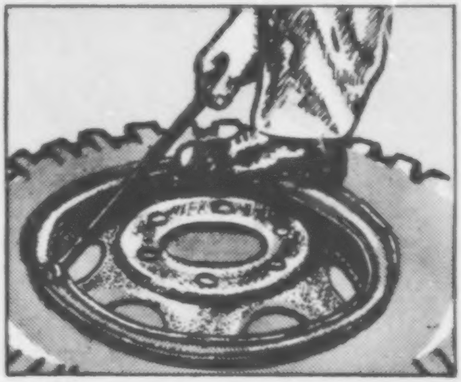
The spreader (fig. 9-17) is used to separate the tire beads enough to allow close inspection and maintenance on the inside of the tire.

The first step in tire changing is to remove the valve core and deflate the tire completely. When using the machine illustrated in figure 9-16, install the tire and rim by closely following the manufacturer's procedures. The machine will then hold the wheel securely and allow you to use the machine's power and attachments to easily remove the tire. All the work is done by the air pressure while you only position the attachment needed for each operation.

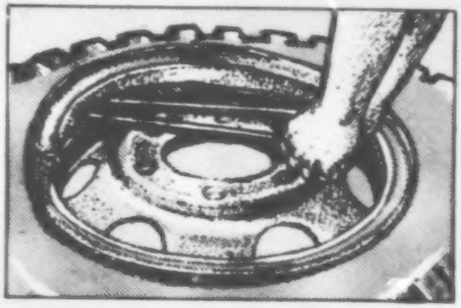
When mounting a tire, inflate the tube until it is almost round. Put the inside bead of the tire on the rim and insert the tube into the tire with the valve at the balance mark on the tire. Place the valve stem through the hole, making sure that is it perpendicular to the hole. This will prevent chafing and damage to the valve stem during vehicle operation. When installing the second bead on the rim, start on the opposite side from the valve stem.

Place the tire and wheel in an approved safety cage and inflate the tire slowly after mounting it on the rim. See that the tire beads fit snugly against the rim flanges. It may be necessary to initially overinflate the tire to cause the bead to seat on the rim. Once seated, allow the tire to deflate and install a new valve core, then reinflate to the recommended pressure.

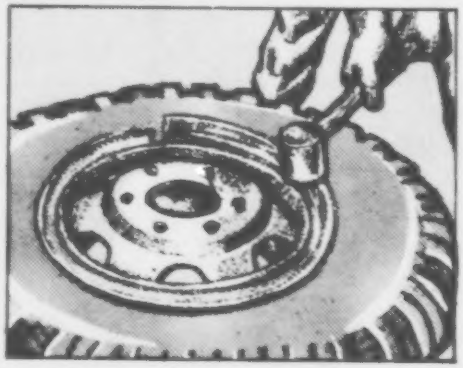
Unless your tire shop is exceptionally well equipped, machinery for repairing truck tires (split rims and rims with removable side rings), will not be available or will not work on all the types of wheels and rims you may encounter. As with the smaller tires, first remove the valve core and deflate the tire. Force the tire bead away from the removable side ring with a slide hammer device intended for this purpose. Next, remove the side ring as shown in figure 9-18, views A and B. Turn the wheel and tire over and



Ⓐ START REMOVING THE SIDE RING AT THE NOTCH



Ⓑ ADVANCE THE TIRE IRONS AROUND THE RIM



Ⓒ AFTER INSTALLING ONE END, TAP AROUND IT WITH A LIGHT HAMMER

81.567

Figure 9-18.—Demounting and mounting the military truck tire.

loosen the other tire bead. Once loose, the tire can be removed from the rim by standing the tire on the tread and prying the wheel out of the tire. Care should be taken to insure the valve stem is not bent or damaged as the wheel is removed.

To replace the tire, position the wheel as shown in figure 9-18, view C. Lower the tire over the rim while at the same time making sure the valve stem is passed through the valve hole and pointing up. (Note: The valve stem should always point toward the removable side ring. If no side ring, point it toward the disk portion of the wheel. This practice is common with all wheels that are disassembled in any manner to remove the tire.) Next, center the side ring and force one end into position with your foot. The ring can then be installed as illustrated or the repair person can merely walk around on top of the ring and it will slide into the locking groove. The inflation steps are the same as for small tires. However, the importance of using a safety cage for inflation cannot be overstressed.

TIRE REMOVAL AND REPLACEMENT (TUBELESS)

All of the lighter commercially designed Navy vehicles and some of the heavier ones are equipped with tubeless tires. Instead of being sealed in an inner tube, the air in these tires is sealed in a space between the outer casing and the rim. Both this space and the point of contact of the tire against the rim must be airtight. The rim, on which the valve for inflating the tire is mounted, becomes a part of the air retaining chamber. Care must be exercised not to tear or otherwise injure the sealing ribs.

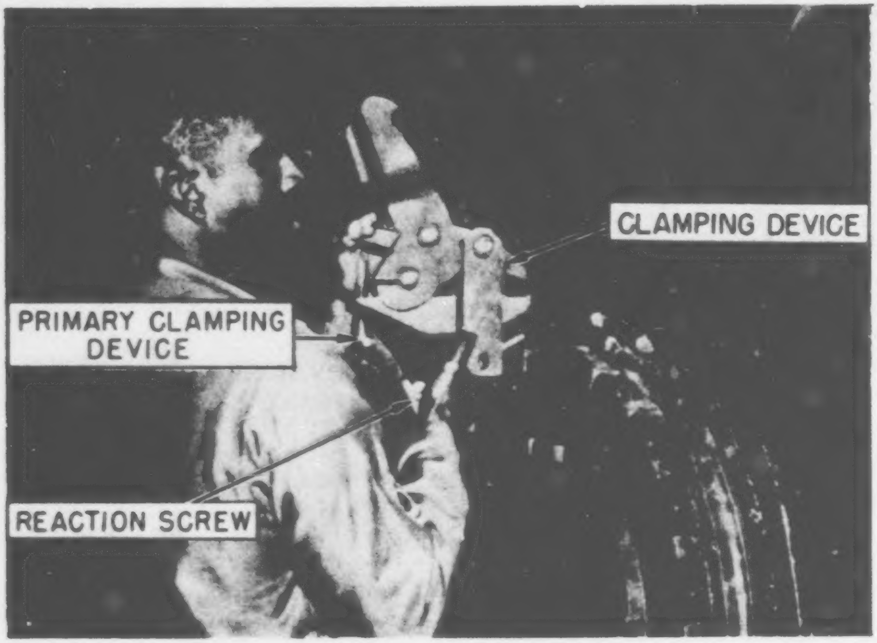
Before replacing a tubeless tire, examine the rim carefully for dents, roughness, and rust, any of which may impair or break the air seal. Straighten out any dents with a hammer, and use steel wool or a wire brush to clean the bead seat area of any rust or grit. After cleaning, paint any bare metal spots where the tire bead seats. This will make it easier should you have occasion to remove the tire at a later time. If the rim is badly bent or out of round, a new wheel should be installed on the vehicle.

Removing and remounting a tubeless tire is similar to the operations for tubed tires. If the tire seal is broken or defective, it will be necessary to use a tube inside the tire. Otherwise, the tire will lose air, and you will have to inflate it frequently. Some tubeless passenger car tires must be removed from the rear of the rim to prevent stretching the bead wires too far and causing them to break. If in doubt about any other details of changing tubeless tires, follow the tire manufacturer's instructions, or consult your chief.

REMOVAL OF LARGE EARTHMOVING TIRE

Some punctures can be repaired without removing the tire. When major damage or a blowout occurs, or normal wear limits have been reached, the tire must be removed. Size alone makes the removal and replacement of earthmoving tires difficult. In addition, the nature of the terrain over which they operate, and location of many operations, often cause conditions to be far from ideal. Certain tools are necessary to change these large tires. The hydraulic bead breaker is specifically designed to break the giant beads, for easier removal of the tire. Before attempting to remove the tire, make sure the wheel has been jacked up and the equipment properly blocked for maximum safety. After the equipment has been safely cribbed, deflate the tire completely. For complete deflation, it is best to remove the valve core.

The clamping device is used to aid in unseating (breaking) the tire beads. It is attached to the rim flange and holds the hydraulic ram and shoe assembly. When securing the clamping device to the rim (fig. 9-19) release the primary clamping screw to permit full opening of the jaws. Hold the clamping device in a vertical position as shown, holding the clamping device in place with one hand and tightening the large clamping screw lightly. Swing the reaction hand, as shown, until it is approximately perpendicular to the side of the rim flange. Turn the reaction screw in to bring the clamping device perpendicular to the rim. Tighten the primary



81.497

Figure 9-19.—Clamping device.

clamping screw firmly by hand. When the clamping device is secured in place, turn the handle on the bottom of the reaction screw. This handle swivels up and down, to permit maximum movement of the clamping device side arms to ease hooking the ram cylinder into place.

The hydraulic cylinder and shoe assembly (fig. 9-20) is actuated by a pump. The pump applies hydraulic pressure, which forces the ram with the attached shoe down between the rim flange and tire bead. This action separates the tire bead and rim.

When securing the ram to the clamping device, place the ram and shoe assembly between the arms of the clamping device, where the bracket of the cylinder is secured into the notches of the clamping device side arms, as shown in figure 9-20.

Applying pressure to the hydraulic cylinder will force the shoe down over the clamping device as shown in figure 9-21. The jaws of the clamping device will act as a guide for the shoe. The convex side of the shoe will bear against the sidewall of the tire, forcing it inward between the tire bead and rim flange, thus breaking loose the bead away from the rim.

Figure 9-21 shows how the wedges are placed on each side of the shoe assembly to hold the bead of the tire away from the rim flange so that the shoe assembly can be easily removed. After the shoe has been forced between the tire bead and rim flange, and freed from that portion of the tire bead, the wedges are inserted to keep the tire bead separated from the rim. Pressure is then removed from the hydraulic cylinder slowly. The hydraulic cylinder and clamping device are then removed from the rim. Place the clamping device approximately 90 degrees from the wedge; continue this process until tire bead is completely free from the rim flange.

TUBE REPAIR

COLD PATCHES are used to repair punctures and small breaks or holes in tubes.

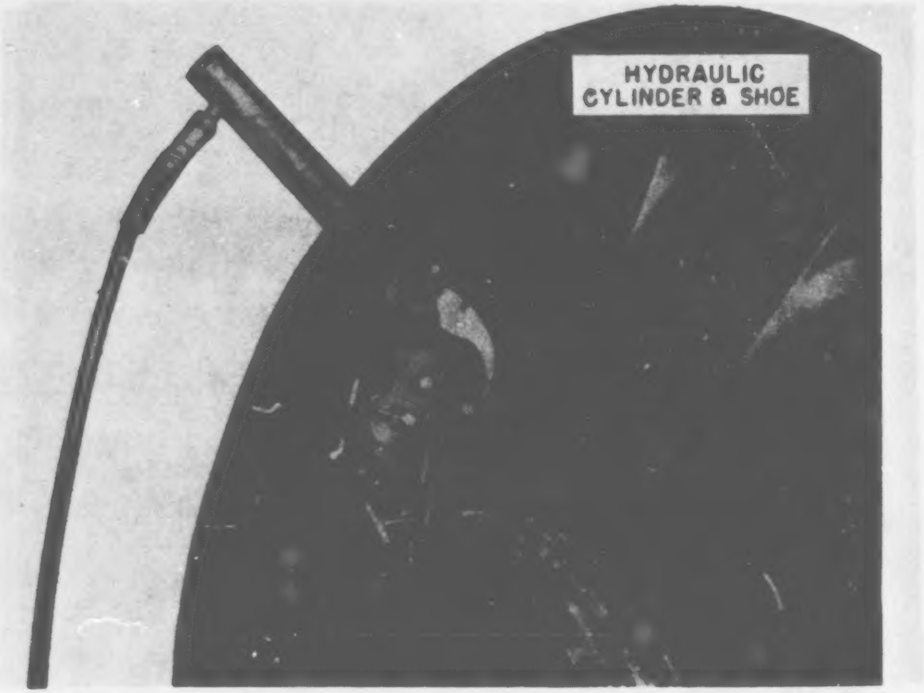


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Figure 9-20.–Hydraulic cylinder and shoe.

You will find cold patching material, rubber cement, and the tools needed in your tube repair kit.

To apply a cold patch, proceed as follows:

1. Buff or roughen the tube surface to be patched for at least 1 inch around the hole. Then clean with solvent. If a buffer is not available, use the perforated cover of the kit as a scraper.
2. Apply a thin coating of rubber patching cement evenly over the roughened surface and allow it to dry.
3. Choose a patch of the proper size (about three-fourths inch larger than the injury or opening) from the kit. Remove the protective covering from the sticky side of the patch, place the patch over the hole, and rub it down firmly.
4. Inflate the tube with enough air to check for leaks. If you cannot hear or feel air escaping from the patch, you can make doubly sure that the tube does not leak by putting it in water. If no escaping air bubbles are noticed, the tube may be dried and replaced in the tire or stored for future use.

HOT PATCHES consist of a slow burning block of fuel held in a notched metal pan, on the bottom of which is a patch of uncured rubber. To apply a hot patch, follow the manufacturer's instructions on the kit.

Although methods of applying patches vary with the clamping devices provided and the shape of the patch, you will clean and roughen the tube just as you did in applying a cold patch. When the patching unit is placed in the notches of the patch and clamped to the tube, the burning material is ignited, allowed to burn, and then removed after cooling for at least 5 minutes. After this, examine the completed patch to see if the edges of the patching material are attached securely to the tube. Then install

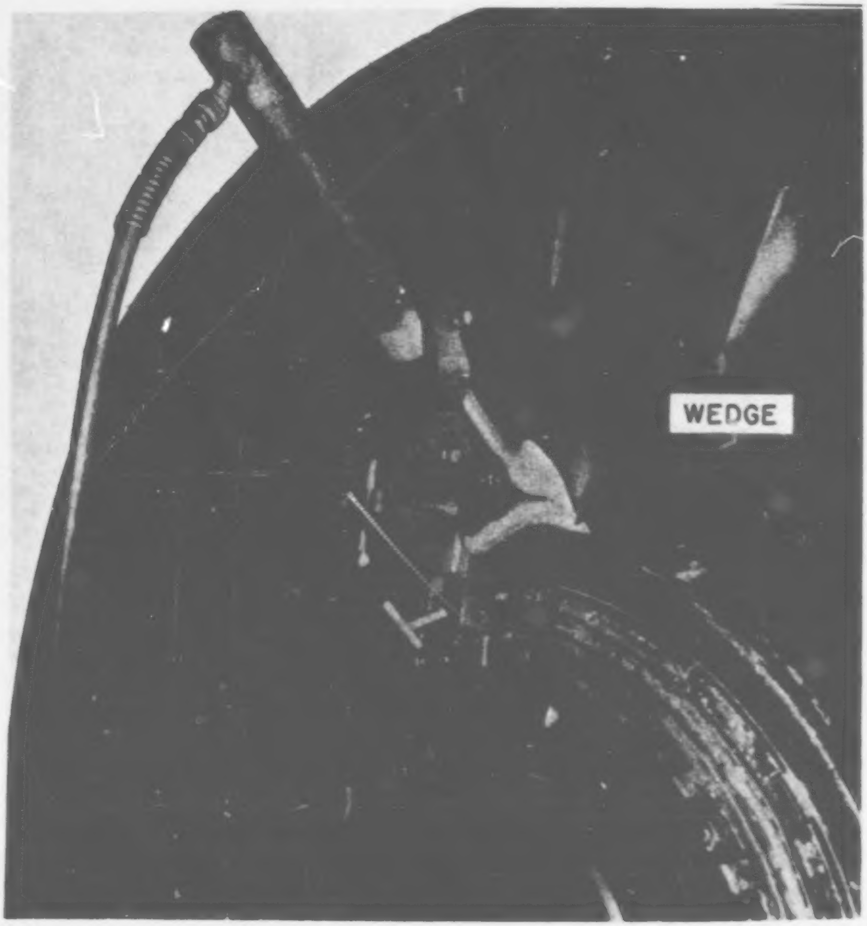

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Figure 9-21.—Operation of hydraulic cylinder and shoe.

the valve core and test the tube. Hot patches of assorted sizes are supplied in kits similar to the cold patch kits. In these also you will find pressure clamps and roughening tools.

TIRE REPAIR

Boots or tire patches should be used only in an emergency. If the tire is tubeless, a tube must be used in conjunction with the boot.

Before applying a boot to the inside of a tire, buff and clean it with solvent; then coat it with adhesive cement. Then remove the fabric backing from the patch. Determine the direction of the first ply of the patch and bend the patch so the center will contact the tire first. Keep in mind that you should place the patch over the injury so that the cords in the first ply of the patch run in the same direction as the cords in the inside ply of the tire. Now press the patch firmly in place, starting in the middle, and working to the edges.

With tubeless tires two other repairs besides the hot and the cold patch are used; the PLUG method, for holes up to three-sixteenths inch in

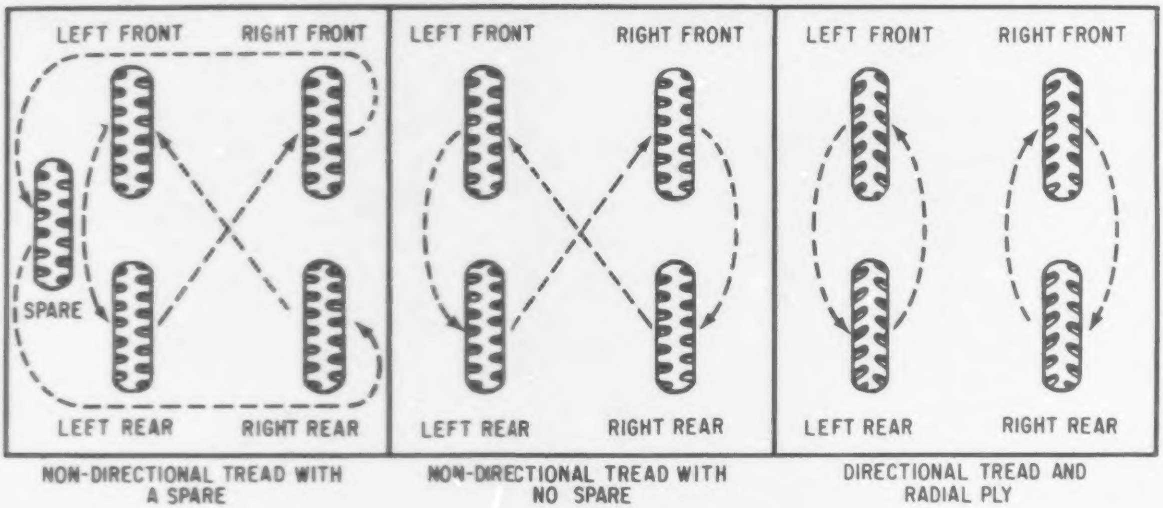

Figure 9-22.–Recommended tire and wheel rotation.

diameter; and the GUN method, for very small holes.

In the plug method, first clean out and puncture the affected place on the tire, then lightly buff the area inside the tire around the puncture for about 3 inches. Next apply rubber cement to this area and allow it to dry. Apply cement also to the repair plug and let it dry. Now attach a wire needle, dipped in the cement, to the plug and push it through the hole from the inside of the tire. The plug should be pulled into place with a steady, continuous pull, without jerking. After the plug is firmly in place inside the tire, use a stitcher to remove air pockets. In trimming the plug, do not stretch it, or the repair will fail.

The gun method does not require removal of the tire from the wheel, and it can be used without deflating the tire completely. Probe the hole with an awl and hand rasp furnished with the tire repair kit and remove any foreign matter, being careful not to enlarge the hole. Then use the resealing gun, turning its screw three or four half-turns to fill the hole.

Should holes in radial tires be in excess of 1/4 inch, or if the puncture is not located somewhere between the two outer tread ribs, the tire should be replaced. Repairs made under these conditions are not considered reliable.

ROTATING TIRES

Rotating tires or changing them from one wheel to another so that they wear evenly is recommended by the manufacturer. This must be done every 5000 miles on Navy vehicles, and entered in the Vehicle Service Jacket. If several tires show more wear than others, or if the mileage is approaching another 5000-mile interval, you will rotate all the vehicle's tires in the following manner:

1. On automobiles having a spare tire, the left front tire should be moved to the left rear, the right front to the spare, the two rears to the opposite front wheels, and the spare to the right rear. (See fig. 9-22.)
2. On automobiles having no spare, move the front tires to the rear on the same side, and move the rear to the opposite front wheels.
3. On vehicles having six tires (dual tires on rear), new tires should normally be mounted on the front wheels for one-third of their life, then moved to the outside rear wheels for another third, and finally shifted to the rear inside

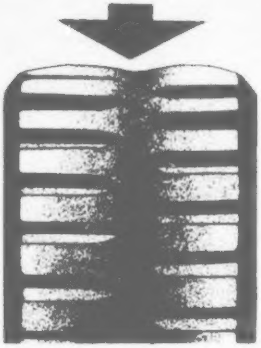

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Figure 9-23.—Overinflation.

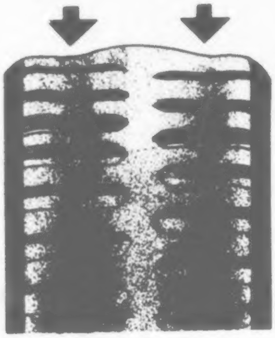

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Figure 9-25.—Underinflation.

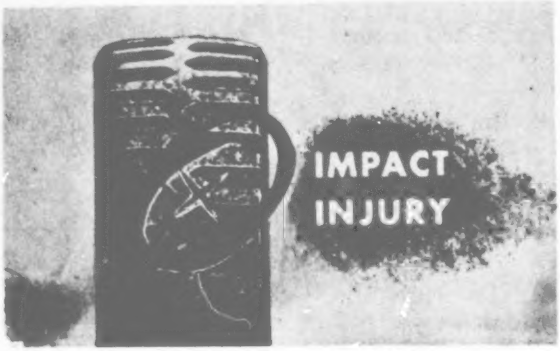

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Figure 9-24.—Overinflation-impact injury.

wheels. A few service conditions which demand maximum traction on rear wheels may require that new tires, or tires with relatively good treads, be mounted on the rear wheels.

PREVENTIVE MAINTENANCE

Pneumatic tires have been installed on many items of equipment to increase mobility and efficiency. However, unless tires are properly cared for, much of this efficiency and mobility is lost.

Probably the greatest factor in prolonging the life of pneumatic tires is PROPER INFLATION. Correct tire pressure cannot be checked by kicking the tire. It requires the use of a pressure gage. Tire pressure checks should be made prior to the vehicle leaving the motor pool. This should be accomplished during the "Before Operation Services." (Don't forget the spare.) If the pressure is neglected, the results can be costly. Tire pressure should be stenciled on the dash or fenders.

OVERINFLATION distends the tire and permits only the center section of the tread to come in contact with the road. Since the wear is concentrated on the central part of the tread, the indication of overinflation is wear in the center of the tread. (See fig. 9-23.) An overinflated tire has no give and is constantly subjected to hard jolts, causing the drive wheels to bounce and spin, literally abrading the rubber. There is also less tire to road surface contact with an overinflated tire and this causes a safety hazard in both braking and sliding.

An overinflated tire is more susceptible to impact injury because the cords are stretched tight. In this condition, the tire will not give or flex and distribute the shock over a larger area of the ply cords. Therefore, when the tire hits an obstacle, the cords may snap and leave a characteristic "X" type break. (See 9-24.)

The external indication of an underinflated tire is more wear on the edges than in the center of the tread. (See fig. 9-25.) UNDERINFLATION causes excessive

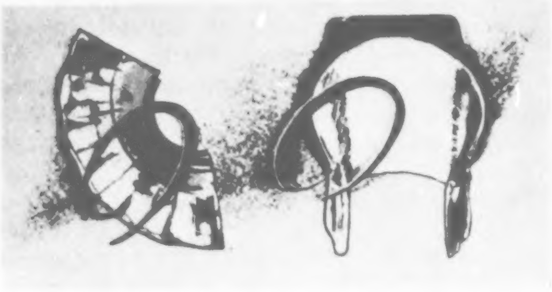

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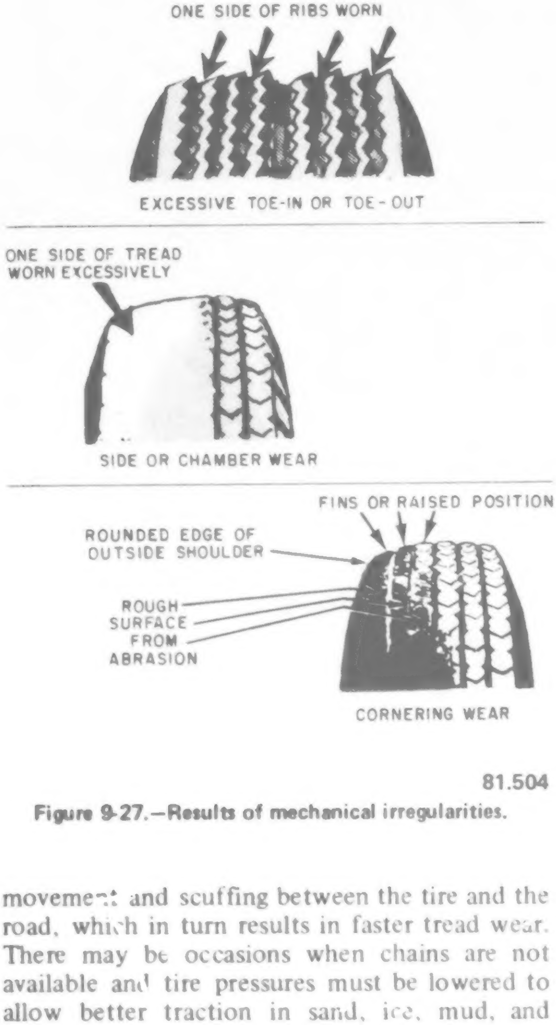
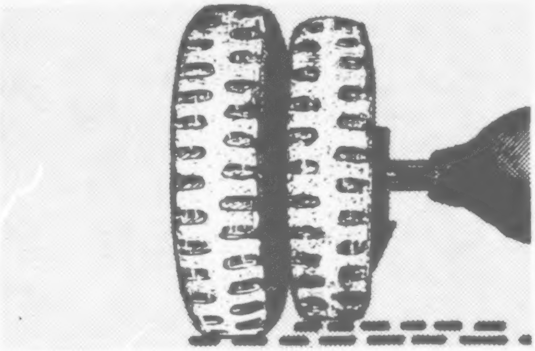
Figure 9-26.–Results of underinflation.


ONE SIDE OF RIBS WORN
EXCESSIVE TOE-IN OR TOE-OUT
ONE SIDE OF TREAD WORN EXCESSIVELY
SIDE OR CHAMBER WEAR
FINS OR RAISED POSITION
ROUNDED EDGE OF OUTSIDE SHOULDER
ROUGH SURFACE FROM ABRASION
CORNERING WEAR

81.504

Figure 9-27.–Results of mechanical irregularities.



81.505

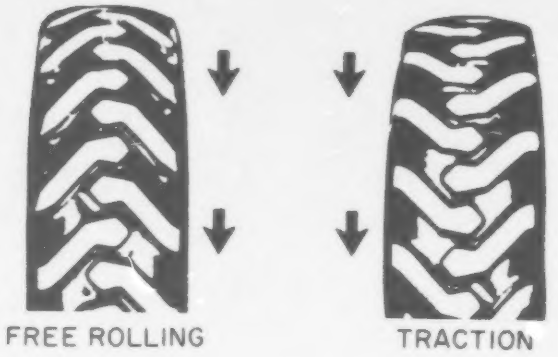
Figure 9-28.–Mismatched tires.

movement and scuffing between the tire and the road, which in turn results in faster tread wear. There may be occasions when chains are not available and tire pressures must be lowered to allow better traction in sand, ice, mud, and snow. When this occurs, prescribed pressures for these conditions should be maintained to prevent tire damage.

A tire that has been run underinflated or flat may have the appearance inside like the tires shown in figure 9-26. The excessive flexing and movement of the ply cords cause a tire to get hot, resulting in separation of cords and rubber. When the cords are separated from the body as shown here, the tire is permanently damaged and must be replaced. While the tire must be removed from the wheel to properly identify this condition, in many instances radial cracks will appear on the outer wall of the tire which will serve as a warning that the tire has been operated underinflated.

Uneven tire wear is often caused by mechanical irregularities on your equipment. Wear of this type (fig. 9-27) can be caused by improperly balanced tires, excessive toe-in or toe-out, improper camber, or operating a vehicle with the front wheel drive engaged on dry hard surfaced roads. When this type of tire wear is encountered, the mechanical defects must be corrected immediately and the tires rotated.

The proper selection and mounting of tires for dual assemblies is extremely important. Mismatched tires will cause uneven distribution of the load, which defeats the purpose of the duals. (See fig. 9-28.) In this case, the larger tire carries the greater load, subjecting it to excessive



81.506

Figure 9-29.—Directional tread tires.

wear and early failure. Usually the smaller tire wears more rapidly. It scuffs along without sufficient road traction causing excessive wear. Since you are not always able to match sizes of tires exactly, except with new tires, certain tolerances are allowed. If the tires are size 8.25 or smaller, a differential in diameter of 1/4 inch is acceptable. On larger tires, over 8.25 up to 1/2 inch is allowable. Even when the tire sizes are not within these tolerances, the larger of the two duals should always be mounted on the outside so that they will conform to the "crown" of the road and shoulder the load more evenly.

Illustrated in figure 9-29 is the directional bar tread type tire. It is commonly used on road graders and other earthmoving equipment. The bars and open center pattern are designed to permit each bar to dig in deep, take a firm hold, and give maximum traction in soft, muddy, or slippery surfaces. Since this is a directional tread tire, it must be mounted on live axles so the point of the "V" comes in contact with the ground first. When the directional tire is mounted in this manner, it is "self-cleaning." It forces the dirt and mud out to the side. When the directional tread tire is mounted on a towed vehicle or on a dead axle, it is mounted so that the open part of the "V" meets the ground first.

A small but necessary item is the valve cap. This cover keeps dirt, water, and grit out of the valve and provides the final seal against air escaping from the tube. For speed and convenience in inflating, valve stems should be readily accessible. They should be positioned to prevent rubbing against the brake drum and to extend through wheel hand holes. Ends of valves on front wheels and inside duals point away from vehicle. Valves on outside duals point toward the vehicle. On dual wheels, valves are placed 180° apart for convenience in checking pressure and inflating.

Rims and rim flanges should be checked regularly to be sure that they are in good condition and fit properly. Since the flange comes in direct contact with the bead which supports the tire, flanges that are bent, broken, chipped, or of the wrong size, put a terrific strain on the bead and lead to early tire failure. (See fig. 9-30.)

Most of the larger wheels and rims used on equipment are the lockring type. The use of the lockring makes tire changing much easier and faster than on the one piece rim of the same size. The principle of the lockring is simple, requiring only that the lockring be firmly seated in the gutter of the rim base. When this is done, the tire and wheel will perform equally as well as the one piece rim. While there is a high safety factor built into the tire and rim assembly, danger results from carelessness or negligence in assembly. Before starting to inflate, make sure that all rim parts are correctly assembled and interlocking. It is mandatory that inflation cages, safety chains, or some other safety device

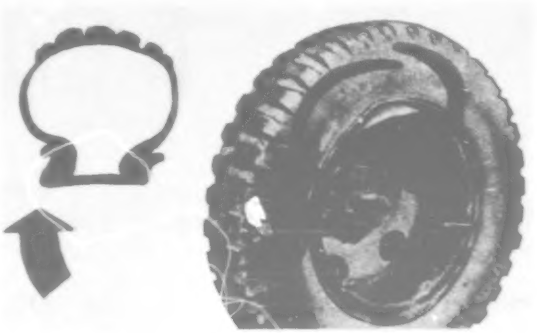


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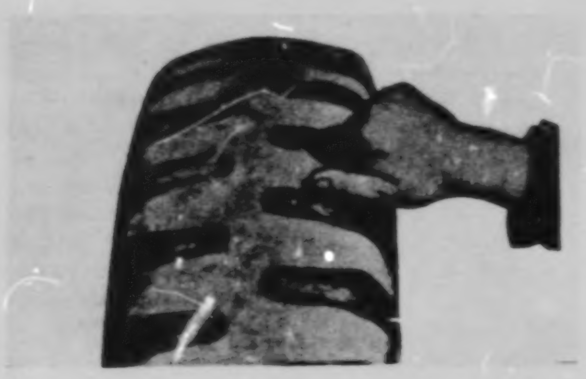
Figure 9-30.—Rim damage.



81.508

Figure 9-31.—Replace worn tires.

be used during inflation. Rims and lockrings should be inspected periodically for damage. A damaged rim or lockring should be replaced immediately as this will create a safety hazard and may ruin a tire. A displaced lockring may spring loose and result in serious injury or death to personnel who may be in the vicinity.

To recap a tire a certain amount of rubber is necessary for the new tread to bond to when it is moulded onto the old carcass. Failure to provide suitable tread will cause the carcass to be rejected as unfit for recapping.

Figure 9-31 illustrates one method of determining tread wear limits. This tire should be replaced when the center of the tire shows no sign of tread. A tire with commercially designed tread should be replaced when less than 1/16" of tread is remaining. If recapping facilities are not utilized, allowable wear before replacement should be based on safety and serviceability.

WHEEL BALANCING

To obtain maximum tire mileage and a comfortable ride, wheels should be balanced to offset the effects of both static and dynamic unbalance. Often a tire will appear to be round and true when rotated slowly, yet give trouble on the road (shimmy or vibrate) when turned fast enough to develop a measurable amount of centrifugal force. This unbalance can be caused by the tire, wheel, brake drum or hub. Or, it may occur in any combination of the four.

When an unbalanced wheel revolves, centrifugal force acts on the heaviest portion and tends to lift the wheel off the road, then slam it down during each revolution. This results in flat spots on the tire tread and rapid wear on the steering and suspension. If the unbalance lies in the plane of wheel rotation, it is known as static unbalance. If it lies on either or both sides of the tire centerline, it is known as dynamic unbalance. Either condition will cause the wheels to bounce. Dynamic unbalance in the front wheels will cause them to wobble as well. Rear wheels should be kept in balance to avoid a bouncing action. Front wheels should be balanced to prevent vibration that will affect steering and cause rapid wear.

Special equipment is used to detect the amount of unbalance. This equipment usually indicates the amount of weight needed and the place where it should be attached to the wheel. Figure 9-32 illustrates the effects of a tire that is out of balance and the location for applying the weights to counteract the unbalanced condition.

Two types of wheel balancing equipment are in use today. One type is designed to correct

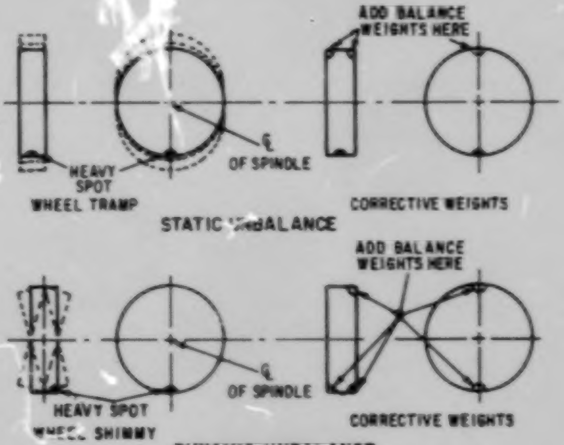


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Figure 9-32.—How weights should be placed when balancing tires.

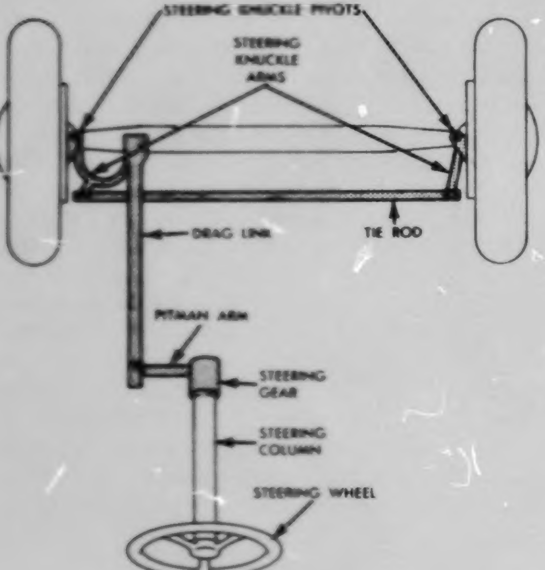

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Figure 9-33.—Steering mechanism.

static unbalance while the other type is used to correct both static and dynamic unbalance. The balancing equipment most often encountered is the "bubble machine". It is widespread because of the low cost and the ease of use. This balancer is excellent when correcting for static unbalance only. The "spin balancer" is preferred because it simulates both static and dynamic conditions that are encountered with the tire and wheel on the car.

STEERING MECHANISMS AND WHEEL ALINEMENT

Automotive steering mechanisms can best be classified as either MANUAL or POWER. In both types, the arrangement and function of the linkage is similar, the main difference being that manual steering requires much more effort from the operator to steer the vehicle.

The components of the manual steering system are steering wheel and shaft, manual gearbox, linkage, and steering knuckle or wheel spindle assemblies (fig. 9-33). The power steering (fig. 9-34) adds a hydraulic pump, fluid reservoir, hoses, lines and a steering assist unit either mounted on the linkage or incorporated with the steering gear assembly.

The steering wheel and shaft enables the operator to steer the vehicle by use of a gear arrangement in the steering gear box. The type of steering gear used is dependent upon the weight of the vehicle and whether or not the steering is power assisted. The type commonly used on automotive equipment assigned to the construction units are the WORM and ROLLER, TWIN CAM and LEVER and the HYDRAULIC (POWER) ASSISTED STEERING.

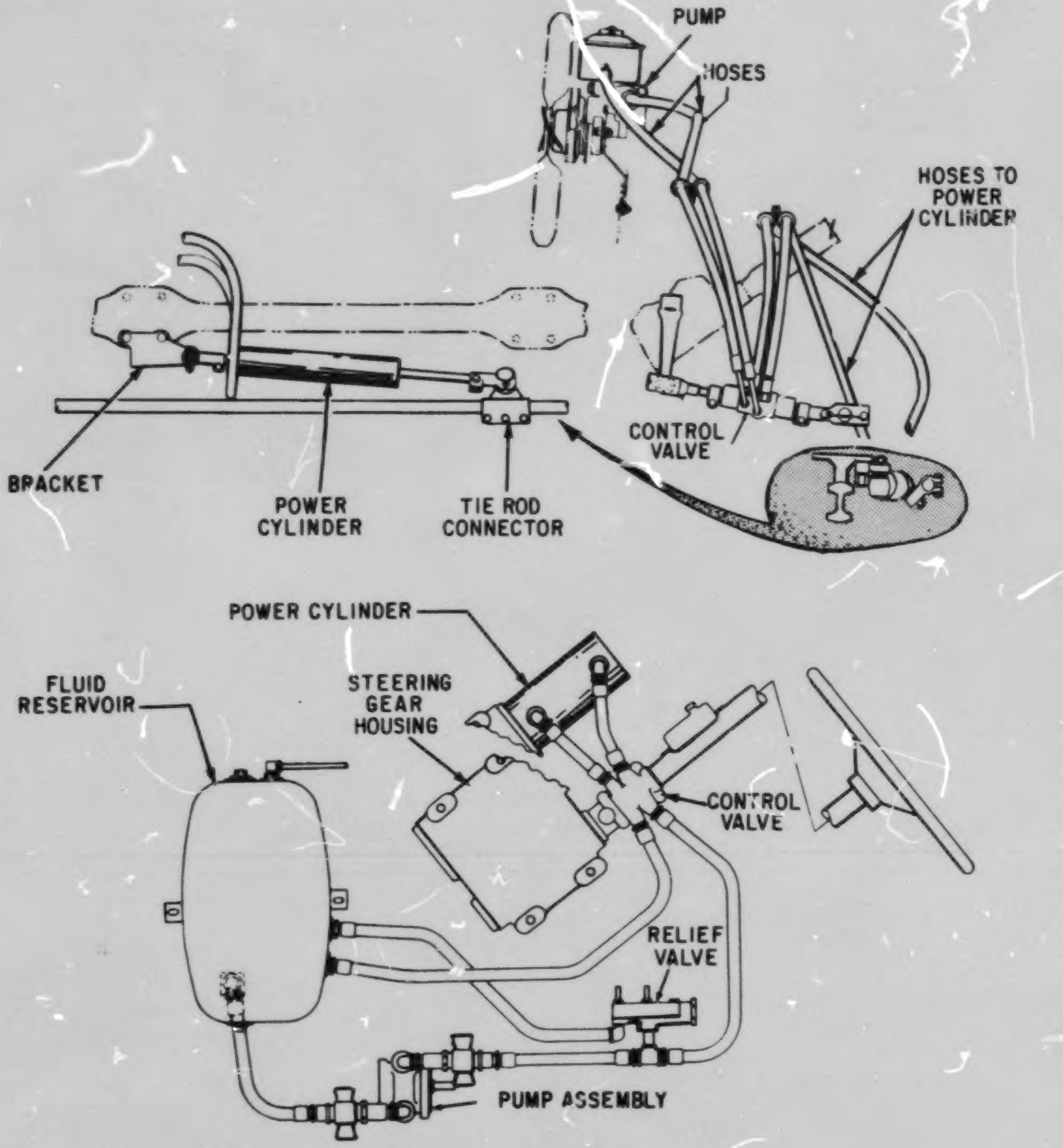
WORM AND ROLLER STEERING GEAR

The worm and roller steering gear is found on light-duty military trucks. This steering gear (fig. 9-35) works well on vehicles that have relatively light front ends. The roller is supported by ball or roller bearings within the sector attached to the pitman arm shaft (cross shaft). These bearings assist in reducing the friction between the worm and sector. As the worm turns, under control of the steering wheel, the roller turns with it and forces the sector and pitman arm shaft to rotate.

Notice how the worm is made in an hourglass shape. This feature causes a variable steering ratio. When the wheels are pointed straight ahead, the gear ratio is high and more movement of the steering wheel is required to turn the wheels. However, as the wheels are cramped or turned to the side, the ratio decreases so that the turning action is much more rapid. This design is helpful when maneuvering the vehicle in confined areas.

CAM AND LEVER STEERING GEAR

The cam and lever steering gear is used on the medium-duty military truck. In this arrangement (fig. 9-36), the worm is referred to as the cam and the sector as the lever. The lever carries two studs that are mounted in bearings and engage with the cam. As the steering wheel is turned, the studs move up and down on the


PUMP
HOSES
HOSES TO POWER CYLINDER
CONTROL VALVE
BRACKET
POWER CYLINDER
TIE ROD CONNECTOR
POWER CYLINDER
FLUID RESERVOIR
STEERING GEAR HOUSING
CONTROL VALVE
RELIEF VALVE
PUMP ASSEMBLY

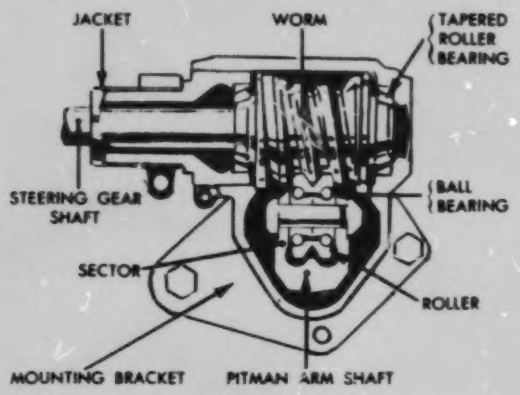
81.569

Figure 9-34.—Two applications of power steering.

cam and cause the lever and pitman arm shaft to rotate. The lever moves more rapidly as it nears either end of the cam. This is caused by the increased angle of the lever in relation to the cam. Like the worm and roller, this design allows for a variable steering ratio.

HYDRAULICALLY ASSISTED STEERING

In the hydraulically assisted steering system, the mechanism which transmits hydraulic power

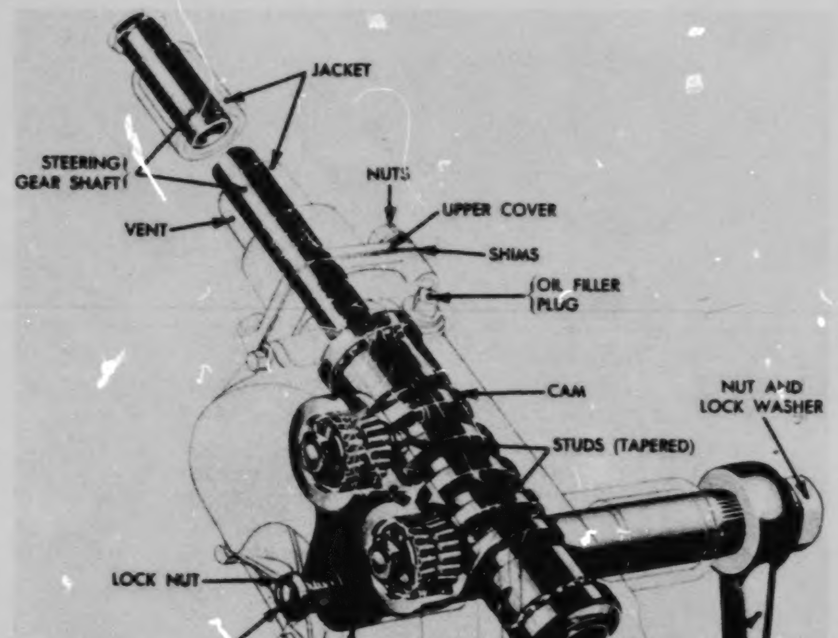

JACKET
WORM
TAPERED ROLLER BEARING
STEERING GEAR SHAFT
BALL BEARING
SECTOR
ROLLER
MOUNTING BRACKET
PITMAN ARM SHAFT

81.570

Figure 9-35.—Worm-and-roller steering gear.

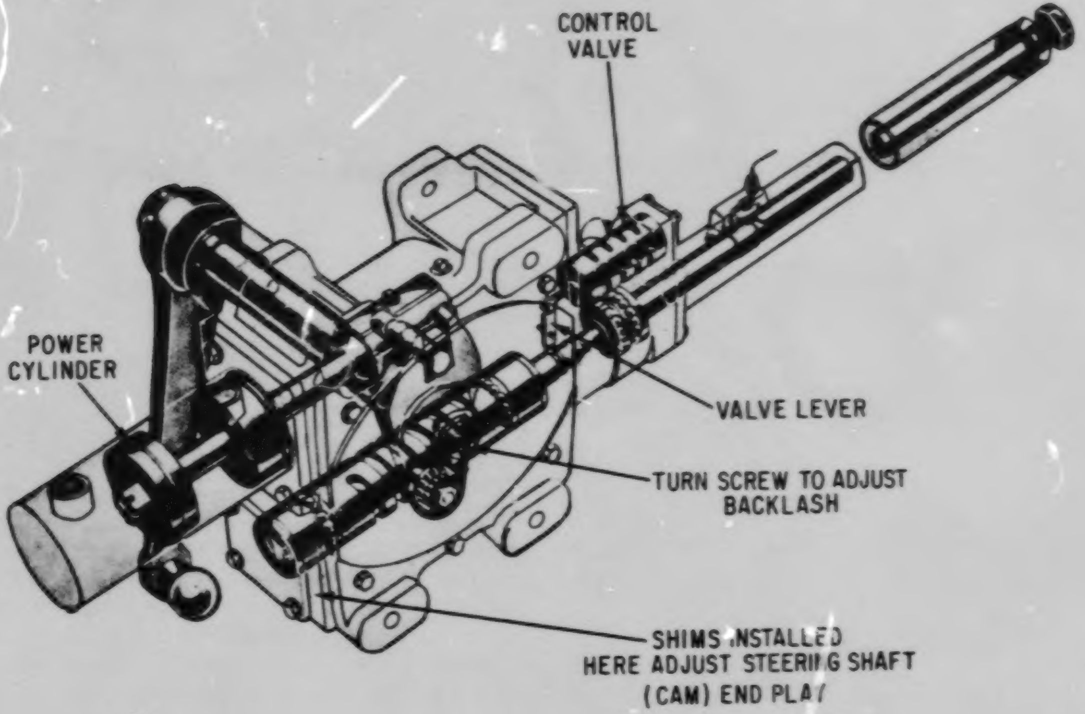
to the steering gear consists of a hydraulic pump, control valve, and power cylinder. The hydraulic power is applied to the cross-shaft through an extension of the lever, which contacts a sliding member connected to the piston of the power cylinder. The flow of oil to the cylinder is directed by the control valve. The steering gear with power cylinder and control valve is shown in figure 9-37. The oil itself is supplied by an external pump driven by the engine. A reservoir must be provided as well as a relief valve which should be set for the desired operating pressure.

The action of this steering gear is both manual and hydraulic in effect. When the cam is turned to the left or right by the driver's effort


JACKET
STEERING GEAR SHAFT
NUTS
UPPER COVER
VENT
SHIMS
OIL FILLER PLUG
CAM
NUT AND LOCK WASHER
STUDS (TAPERED)
LOCK NUT
ADJUSTING SCREW
PITMAN ARM
LEVER SHAFT

81.256

Figure 9-36.—Cam-and-twin-lever steering gear.


CONTROL VALVE
POWER CYLINDER
VALVE LEVER
TURN SCREW TO ADJUST BACKLASH
SHIMS INSTALLED HERE ADJUST STEERING SHAFT (CAM) END PLAY

2.426

Figure 9-37.—Phantom view of power steering gear.

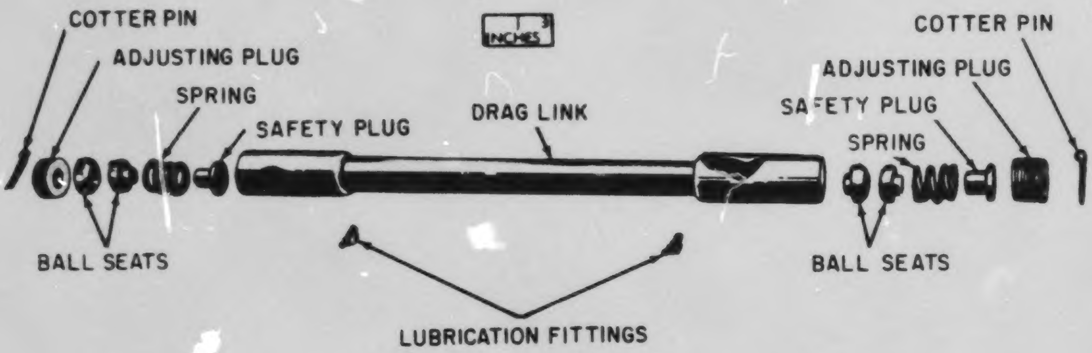
on the steering wheel, the stud of the lever is moved through the groove of the cam, thus rotating the levershaft and providing angular movement of the steering arm. However, when the driver's effort at the steering wheel exceeds the preload of the cam centering springs, the hydraulic system comes into operation automatically and relieves the driver of excessive loads. In addition, the hydraulic system resists kickbacks or shock, which might otherwise cause the driver to lose control of the vehicle.

The control valve contains oil passages that direct the flow of oil under pressure to the appropriate end of the power cylinder when the spool is caused to move within the housing. The power cylinder in turn applies power to the lever and shaft assembly through mechanical linkage. The control valve provides for the return of oil from the discharge side of the power cylinder.

The spool is held in the center position by means of the cam centering springs. These springs are compressed to a predetermined load and installed as a self-contained assembly at each end of the cam. The effect of the springs is to center the cam, and, in turn, the valve spool, unless the steering force is great enough to overcome the spring load, in which case the cam is displaced a slight amount. As the cam moves in either direction, the valve lever transmits motion to the spool valve, and allows oil under pressure to actuate the piston in the power cylinder. Full pressure is obtained with a cam travel of only a few thousandths of an inch.

When the effort at the steering wheel is sufficiently reduced, the cam and spool valve return to the center position.

If the steered wheels are subjected to road shock, the pitman arm, acting through the



81.571

Figure 9-38.—Drag link assembly—exploded view.

steering gear shift the cam and control valve. This will direct fluid to the piston causing a resistance to any movement due to shock. This blocking action of the gear prevents kickbacks at the steering wheel.

When the control valve is in the center position, steering action is strictly manual. This enables the driver to obtain the feeling of "road-sense," which permits the sense of touch to assist the sense of sight. Road-sense is fully appreciated by experienced drivers and is desirable for safety reasons.

STEERING SYSTEM MAINTENANCE

Maintenance of the steering system consists of regular inspection, lubrication, and an occasional adjustment to compensate for wear and maintain proper wheel alinement. When inspecting the steering mechanism, you may need someone to assist you by turning the steering wheel back and forth through the free play while you check the linkage and connections. This will allow you to more easily determine if the steering gear is secured rigidly to the frame and no excessive looseness of the linkage or gearbox is present. A slight amount of free play may seem insignificant, but if allowed to remain, the free play will quickly increase and result in poor steering control.

Depending on the steering arrangement, a drag link or idler arm rod may be used in the linkage to connect the pitman arm and the remainder of the steering linkage. This portion of the linkage is usually constructed so that in order to remove it from the vehicle one or both ends must be disassembled or loosened. The adjusting plug (fig. 9-38) is used to remove any free play between the drag link and the connecting parts of the linkage when installed. Occasionally, adjustment of the plug is needed to compensate for wear of the ball and seats or weakening of the spring.

The tie rod, or rods, are equipped with a ball type socket at each end to allow for movement of the connecting parts of the steering linkage. These sockets called TIE-ROD ENDS must be checked for wear or slack. The linkage should pivot at the ball socket without allowing free movement between the socket and ball. A slight drag is considered the optimum condition of the ball joints. In addition to the flexible end connections, an adjustment is provided by the design of the linkage when performing wheel alinement. The tie-rod is normally connected directly to the steering knuckle or spindle arm and used to transmit the steering effort to the wheel via the knuckle or spindle.

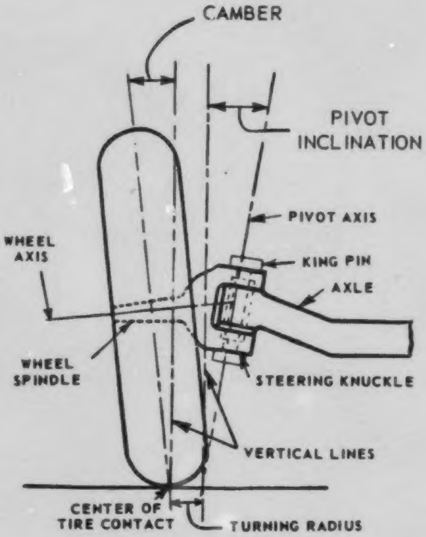
In addition to linkage maintenance, there are other items in power or hydraulically assisted steering systems that must be inspected for condition and operability. If the pump is belt driven, the first item to check is the condition of the drive belt. Make sure that it is sufficiently tight to prevent slippage yet loose enough to prevent damage to the shaft bearings. If in doubt as to the proper adjustment, check the manufacturer's specifications in the operator's or maintenance manual. The fluid level in the reservoir should be checked at each maintenance cycle and kept above the add or low mark. Inspect the hoses and connections for signs of leakage. If leaks are present, repairs should be made as soon as possible due to the small amount of fluid that can be lost from the system without damage resulting to the pump. When checking the linkage of a vehicle with power steering, make sure that the inspection is thorough. The power steering system will absorb much of the looseness or slack which would be readily apparent in manual steering. Because of this, wear of the linkage will normally progress to a dangerous point before the average operator becomes aware of any fault. Additionally, the pressure of the steering pump may be checked to determine if it is the problem, should hard steering occur. To determine the pressure of the system, a suitable pressure gage and fittings will be needed. This check should be made by using the manufacturer's procedures and comparing the results to the specifications. If not within limits, a faulty component must be replaced. Pressure can be changed by altering spring tension in the relief valve.

WHEEL ALINEMENT

Steering control depends greatly upon the position of the wheels in relation to the rest of the vehicle and the surface over which it travels. Any changes from the specified setting of the wheels affect steering and the riding control of the vehicle. Therefore, the proper WHEEL ALINEMENT is important for vehicle control.

Steering Geometry

STEERING GEOMETRY is the term manufacturers use to describe steering and front wheel alinement. Steering geometry includes PIVOT INCLINATION, CASTER, CAMBER, TOE-IN, AND TOE-OUT. These terms refer to measurements in inches or angles that determine front wheel alinement. These measurements may change as a result of driving over rough terrain, striking stationary objects, accident damage, and normal wear.



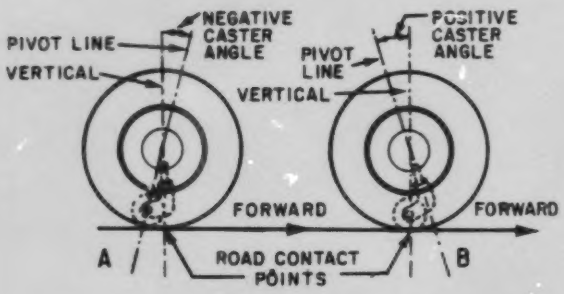
81.260

Figure 9-39.—Pivot inclination and camber.

PIVOT INCLINATION (sometimes called KINGPIN ANGLE) (fig. 9-39) is the number of degrees that the king pin is tilted toward the center of the vehicle from a vertical position. Pivot inclination keeps the wheel spindles pointed outward and in line with the axle, and helps to make steering easier. Pivot inclination is designed into the spindle assembly on vehicles with independent front suspension.

CASTER is the number of degrees that the steering knuckle pivots or spindle assembly is tilted to the rear or to the front (fig. 9-40). Positive caster tends to keep the front wheels pointed straight ahead and will cause them to return to the straight ahead position if the steering wheel is released while the vehicle is in motion and the wheels are turned.

As an example of how caster works, consider the front wheel of a bicycle. When the wheel is turned from the straight ahead position the



81.261
Figure 9-40.—A. Negative Caster. B. Positive Caster

front end is raised slightly. The weight of the bicycle forces the front end down and helps to straighten the wheel. This is the method used on the modern automobile. As front end sheet metal extended further and engines with accessories increased in weight, the amount of positive caster needed for easy steering lessened.

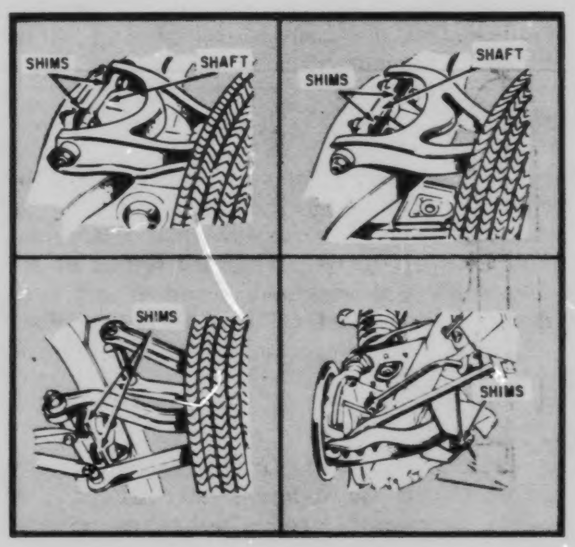
The increased weight on the front wheels and the change from solid front axles to independent suspension have reduced the need for caster. Some vehicles may be designed for 0° positive caster while the maximum with a solid axle is approximately 8°.

Caster in commercial vehicles with front leaf springs is adjusted by inserting wedges or shims between the front axle and the spring so that the steering knuckle pivots are tilted slightly backward from the vertical. Many vehicles with independent suspension have provisions for this adjustment by the use of shims (fig. 9-41), while others are adjusted by the use of eccentrics or an adjustable strut (fig. 9-42). If the knuckle pivots (kingpins or balljoints) are tilted forward, the caster is said to be negative. The caster is said to be positive when the knuckle pivots are tilted backward.

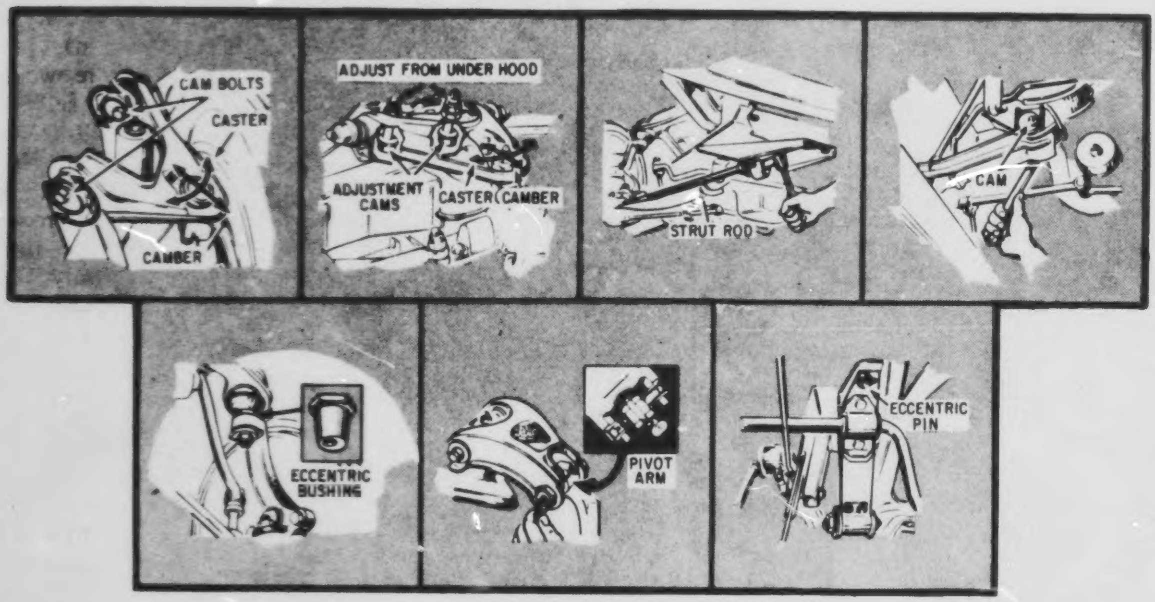
CAMBER (fig. 9-39) is the number of degrees that the wheels are tilted in or out at the top. Wheels having positive camber are closer together at the bottom than they are at the top. Camber, together with pivot inclination, reduces sidethrust on the kingpin bearings in the steering knuckle and support, (ball joints and control arm bushings if independent suspension), thus permitting easier steering and less tire wear. Camber angle, in today's vehicles, very seldom exceeds one degree and is obtained by tilting the wheel spindles slightly downward on the steering knuckles. Camber brings the wheels perpendicular to the surface of the road, permitting even tread wear across the tire. Excessive camber will cause wear on only one side of the tread and early tire failure. Camber is adjusted by shims or eccentrics much like caster.

TOE-IN (fig. 9-43) is the fraction of an inch that the leading edge of the front wheels point in toward the center of the vehicle. When forced to follow a straight path by motion of the vehicle, cambered wheels tend to slip away from each other. But toe-in causes the wheels to travel toward each other and, therefore, balance the effect of camber.

TOE-OUT during turns is the difference in the turning radius of the outer wheel, with the inner wheel turned out at a 20-degree angle. Toe-out is necessary because of the different turning radius

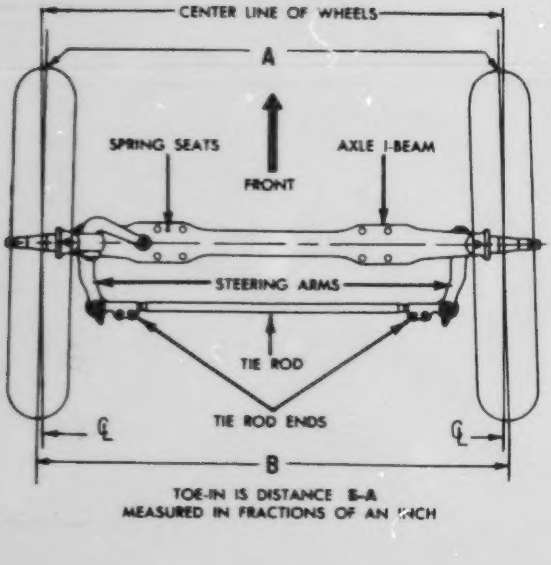


81.572
Figure 9-41.—Wheel alinement adjusted by shims.


CAM BOLTS
CASTER
CAMBER
ADJUST FROM UNDER HOOD
ADJUSTMENT CAMS
CASTER
CAMBER
STRUT ROD
CAM
ECCENTRIC BUSHING
PIVOT ARM
ECCENTRIC PIN

81.573

Figure 9-42.–Wheel alinement adjusted by eccentrics or strut rods.


CENTER LINE OF WHEELS
A
SPRING SEATS
FRONT
AXLE I-BEAM
STEERING ARMS
TIE ROD
TIE ROD ENDS
℄
℄
B
TOE-IN IS DISTANCE B-A
MEASURED IN FRACTIONS OF AN INCH

81.262

Figure 9-43.–Toe-in.

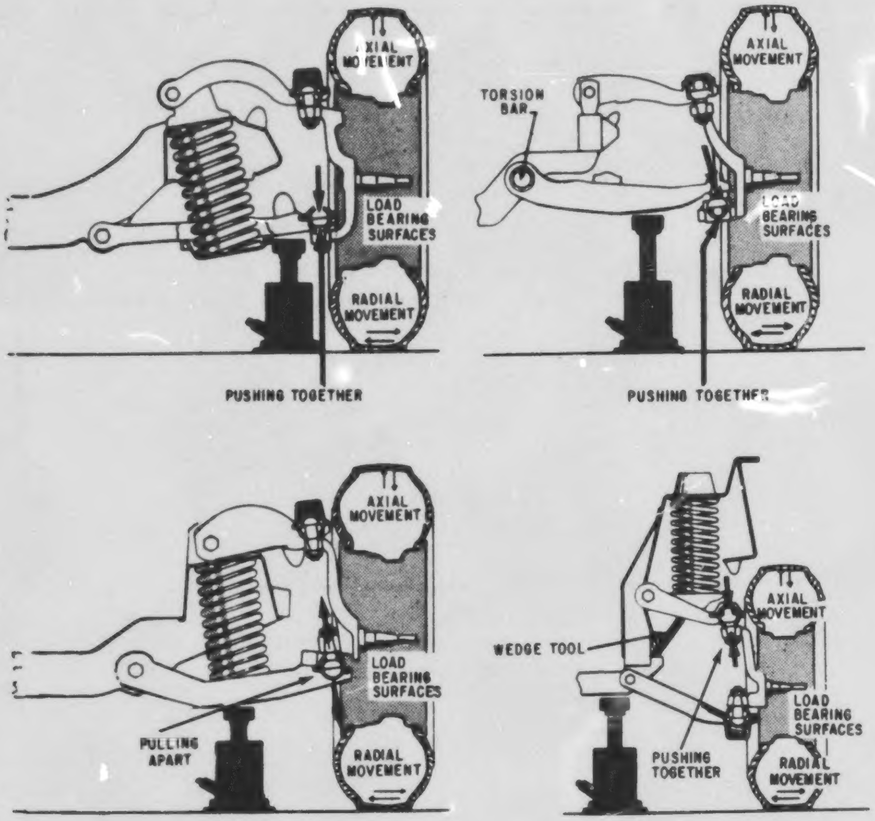
of the front wheels and the necessity of preventing slipping of the front wheels when turning. Toe-out is a design feature of the steering arm for which there is no required adjustment.

Steering and Alinement Troubles

The driver can sense steering and alinement troubles. He can detect hard steering or play in the steering system. But he will call on you to find the trouble and to remedy it.

Some steering wheel play is normal and provides for easier steering of the vehicle.

A lot of play, more than 3 inches as measured at the outer rim of the steering wheel, means a freer movement of the steering wheel with no motion at the wheels. Too much wheel play is caused by improper adjustment or wear of the steering gear, steering linkage, steering knuckle plates, or loose wheel bearings. You can check for worn or loose linkage connections by jacking up each front wheel (fig. 9-44). Grasp the tire at the front and back and attempt to shake the tire rapidly in the direction that it


AXIAL MOVEMENT
LOAD BEARING SURFACES
RADIAL MOVEMENT
PUSHING TOGETHER
TORSION BAR
AXIAL MOVEMENT
LOAD BEARING SURFACES
RADIAL MOVEMENT
PUSHING TOGETHER
AXIAL MOVEMENT
LOAD BEARING SURFACES
PULLING APART
RADIAL MOVEMENT
WEDGE TOOL
AXIAL MOVEMENT
LOAD BEARING SURFACES
PUSHING TOGETHER
RADIAL MOVEMENT

81.574

Figure 9-44.—Jacking positions used when checking independent front suspension for wear.

moves when turning. While the vehicle is elevated, check the steering knuckle parts and/or kingpins, ball joints, and wheel bearings by placing a small iron bar under the wheel and shaking it up and down.

Test the steering gear by watching the pitman arm while someone turns the steering wheel one way and then the other. If considerable movement of the steering wheel is required to set the pitman arm in motion, the steering gear is either worn or out of adjustment.

Hard steering may be caused by very tight adjustments, mechanical difficulties in the steering gear or linkages, not enough air in the tires, or improper wheel alinement.

Sometimes the driver may tell you that his vehicle "wanders." It may be that he tends to oversteer the vehicle. Nevertheless, you should check the vehicle for low tire pressures, improper front wheel alinement, and tight or loose wheel and brake adjustments. "Pulling" of the vehicle when braking could be caused by grabbing brakes. If it "pulls" when driven, check for proper toe-in and toe-out, besides the other causes already mentioned.

Steering shocks, which is the sharp and rapid movement of the steering wheel, may be the result of driving over a rough road or hitting objects on the road. When the vehicle does not steer properly, you should check for sagging springs, defective shock absorbers, or looseness in the steering gear or linkage. Uneven tire inflation also could be the cause.

If the power steering mechanism fails, the steering system will go back to straight mechanical operation. Consult the manufacturer's manual for instructions on repairing power steering units.

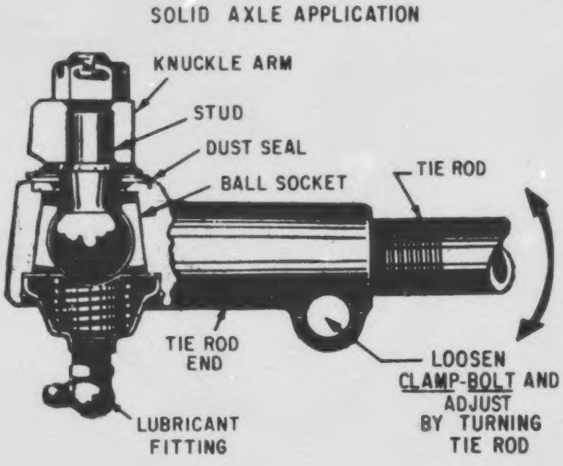
If your shop has floating turntables, use them to check steering errors. Run the vehicle up on the tables, then turn the front wheels with the steering wheel. Each floating table will turn with the wheel on it and register the angle of the turn. When the inner wheel turns out 20 degrees, the outer wheel should turn about 18 degrees.

Before checking front wheel alinement, be sure that the front tires are properly inflated, and that steering knuckles and linkages, shock absorbers, and the wheel bearings are correctly adjusted. A number of devices may be used for testing toe-in. One of these, the WEE-GEE BOARD, consists of a metal plate fastened at one end and free to sideswing on the supporting balls. The board measures the sideslip of the tire. When the vehicle is run over the board, watch the indicator as the board moves. If the indicator moves toward the center of the vehicle, the wheels need more toe-in. On the other hand, if the indicator moves away from the center of the vehicle, the wheels have too much toe-in. The WEE-GEE board is not considered to be a very accurate device for measuring wheel alinement but may be used to indicate the need for alinement using more accurate measuring devices.

Another device for measuring toe-in is the MEASURING POLE. There is an adjustable pointer and a gage on one end, and the pole can be lengthened and shortened like a curtain rod.

With the vehicle resting on a level floor and the wheels in a straight ahead position, push the vehicle forward a few feet to remove all play in the steering assembly. Put pencil marks on the inside walls of the tires at axle height from the floor, and at both the front and rear of the tire.

Place the pole between the two marks at the front of the tire and set the pointer at zero. Then, use the pole to measure the distance between the two rear marks. The difference in the distance between the two measurements should conform to the manufacturer's specifications. If not, changing the length of the tie-rod will increase or decrease the toe-in. IF THE VEHICLE HAS TWO TIE-RODS, IT IS NECESSARY TO ADJUST EACH TIE-ROD EQUALLY.

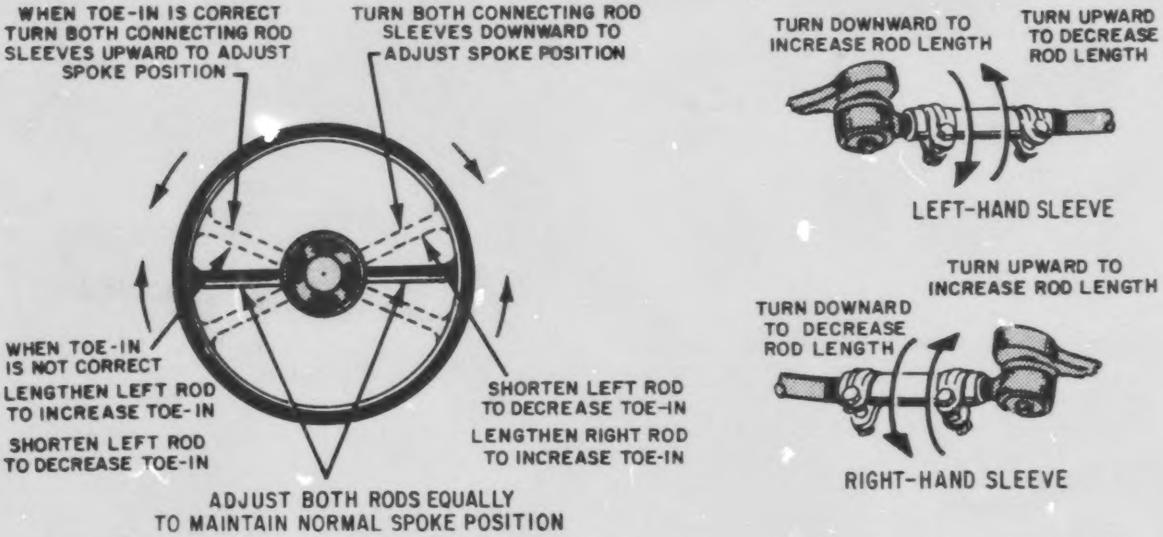


81.264

Figure 9-45.–Tie-rod end showing clamp bolt and adjusting threads.

Toe-in adjustment on vehicles with solid front axles, is quite simple. Loosen the clamps (fig. 9-45) at both ends of the tie rod, and with a pipe wrench or other suitable tool, turn the tie rod to either lengthen or shorten as desired until you obtain the proper adjustment. Vehicles with independent suspension are equipped with two tie rods and both must be adjusted at the same time to keep the steering wheel in the proper position when the wheels are pointed straight ahead (fig. 9-46). If after obtaining the correct toe-in adjustment, you find the steering wheel off center, you can center it by turning one adjusting sleeve in one direction while turning the other an equal amount in the opposite direction. Adjusting toe-in is not a difficult task. Proper use of the alinement equipment along with reference to a set of specifications provided by the vehicle or alinement equipment manufacturer will be all you need.

Caster and camber adjustments require the use of special shop equipment that is not available in the average SEABEE maintenance shop. Other considerations are that the equipment is expensive and the only vehicle contained in the organic allowance that requires


WHEN TOE-IN IS CORRECT TURN BOTH CONNECTING ROD SLEEVES UPWARD TO ADJUST SPOKE POSITION
TURN BOTH CONNECTING ROD SLEEVES DOWNWARD TO ADJUST SPOKE POSITION
TURN DOWNWARD TO INCREASE ROD LENGTH
TURN UPWARD TO DECREASE ROD LENGTH
LEFT-HAND SLEEVE
TURN UPWARD TO INCREASE ROD LENGTH
TURN DOWNARD TO DECREASE ROD LENGTH
WHEN TOE-IN IS NOT CORRECT
LENGTHEN LEFT ROD TO INCREASE TOE-IN
SHORTEN LEFT ROD TO DECREASE TOE-IN
SHORTEN LEFT ROD TO DECREASE TOE-IN
LENGTHEN RIGHT ROD TO INCREASE TOE-IN
RIGHT-HAND SLEEVE
ADJUST BOTH RODS EQUALLY TO MAINTAIN NORMAL SPOKE POSITION

81.575

Figure 9-46.—Toe-in adjustment on vehicles with independent suspension.

these adjustments is the jeep, which seldom needs front end alinement.

Front suspensions that are adjusted by shims are shown in figure 9-41 require adding or removing an equal amount of shims at each location to change camber. Caster is adjusted by varying the amount of shims at one or both locations. This method of adjustment is used on the military jeep. Figure 9-42 illustrates adjustment by use of eccentrics or altering the length of strut rods. You may find some front suspensions that use a combination of these two methods of adjustment. Any time you are to perform front end alinement, carefully follow the manufacturer's procedures. Slight errors in these adjustments will cause rapid tire wear and hard steering control.

BODIES

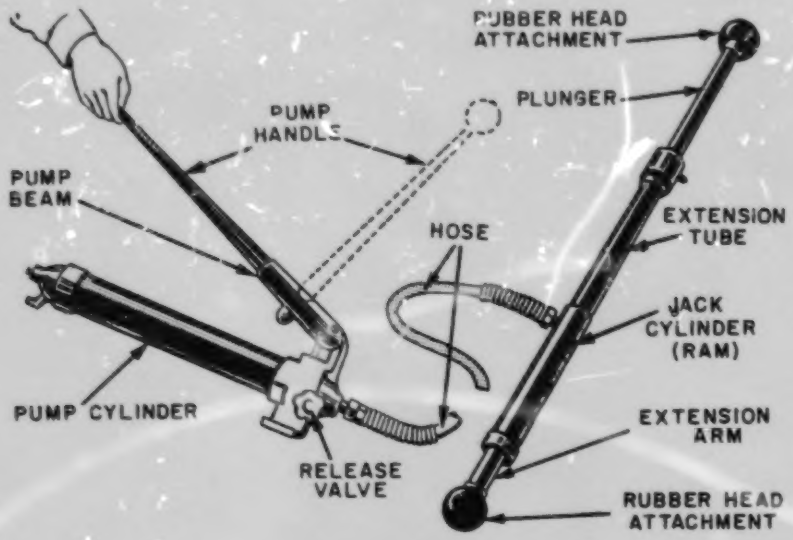
The automotive body provides protection for the engine, power train components, operator, and any cargo or passengers. At the same time, it adds strength to the frame and provides adequate vision for the operator. Last, but not least, the body design provides a pleasant outward appearance.

For military designed vehicles, appearance is secondary. NAVFAC (who controls all Navy vehicles) states that transportation equipment will be repainted when inadequate protection is afforded against rust or corrosion. Also that spot painting should be used instead of complete painting unless necessary for protection of the entire vehicle.

Part of your job as a Construction Mechanic is to perform body maintenance on the vehicles assigned to your command. In order to perform this task, you must know some of the procedures used for straightening fenders and body panels. Preparation and painting of the vehicles is another important task associated with this responsibility.

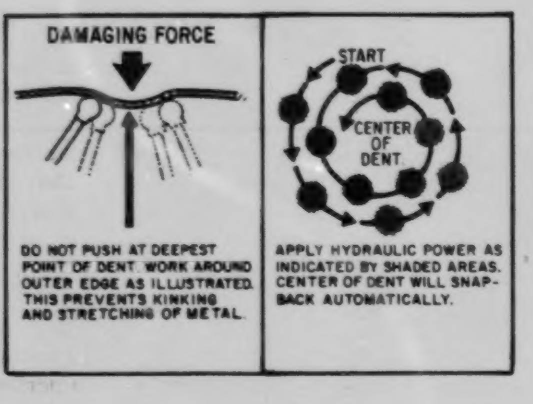
Regardless of whether the vehicle is in need of extensive body work or has a dented fender, it is desirable to have a number of special tools to use.

One of the most important tools needed to repair heavily damaged fenders is the portable


RUBBER HEAD
ATTACHMENT
PLUNGER
PUMP
HANDLE
PUMP
BEAM
HOSE
EXTENSION
TUBE
JACK
CYLINDER
(RAM)
PUMP CYLINDER
EXTENSION
ARM
RELEASE
VALVE
RUBBER HEAD
ATTACHMENT

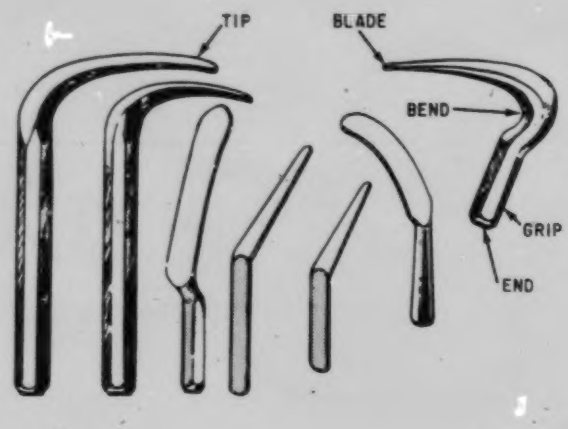
81.576

Figure 9-47.–Portable hydraulic jack.


DAMAGING FORCE
DO NOT PUSH AT DEEPEST POINT OF DENT. WORK AROUND OUTER EDGE AS ILLUSTRATED. THIS PREVENTS KINKING AND STRETCHING OF METAL.
START
CENTER
OF
DENT
APPLY HYDRAULIC POWER AS INDICATED BY SHADED AREAS. CENTER OF DENT WILL SNAP-BACK AUTOMATICALLY.

81.577

Figure 9-48.–Pushing body dent out.

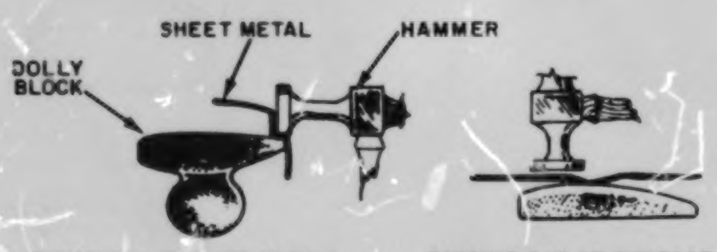

TIP
BLADE
BEND
GRIP
END

81.578

Figure 9-49.–Spoons used in the body repair shop.

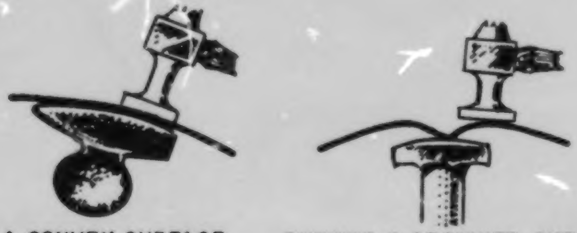
hydraulic jack (porta-power) shown in figure 9-47. This tool when applied as shown in figure 9-48 will force the damaged portion to return to near original shape and save many hours of labor. The porta-power is provided with a number of adapters or accessories that allow you to use it in many types of body repair work.

Figures 9-49 and 9-50 illustrate some of the tools used in the body repair shop. Some words of caution with the use these tools are to make sure the surfaces of the spoons, hammers, and dollies you are going to use are free from scratches and/or dents. Surface defects on the tools will cause similar defects in the sheet metal

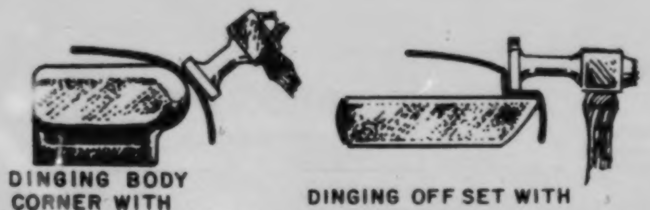


DINGING A FLANGE WITH A LOW-CROWN GENERAL PURPOSE DOLLY

DINGING A FLAT SURFACE WITH A TOE DOLLY


DINGING A CONVEX SURFACE WITH A HIGH-CROWN GENERAL PURPOSE DOLLY

DINGING A CROWNED SURFACE WITH A HIGH-CROWN MUSHROOM DOLLY


DINGING BODY CORNER WITH A HEAVY-DUTY GENERAL PURPOSE DOLLY

DINGING OFF SET WITH A HEEL DOLLY

81.579

Figure 9-50.—Using dolly blocks to shape body panels.

they are used on. To remove surface defects, use a file and fine grit sandpaper until you again have a smooth surface.

With these tools, and experience gained by practicing on old discarded body parts, you will be able to remove the dents and creases while restoring the body to a like new condition. The ease and speed with which you can straighten the sheet metal is dependent on starting the repair work at the right point and correct use of the tools provided. If this is done, the amount of "dinging" (light tapping of the metal with the hammer) required to remove the dent is reduced considerably. As metal is dinged and formed, a certain amount of stretching occurs. This will cause additional work if excessive when nearing the completion of the repair. Always remember, when straightening a damaged panel, the damage should be removed in the reverse order of how it occured.

REMOVING DENTS

Before attempting any body repairs, scrape off any undercoating or foreign matter located in the area to be repaired. Dirt or undercoating will cake on the dolly block. No amount of hammering will produce a smooth surface when this occurs. Next make sure the outer side is clean to protect the hammer.

Without prior body repairing experience, a mechanic will usually start applying pressure at the spot where the panel was struck first and is depressed the most. The CORRECT METHOD is to apply pressure at the ridge farthest from the point of impact. To make the procedure clear, refer to the damaged panel in figure 9-51. Assume that the original form of the panel is shown as the dotted line. Point Y is where it was struck, and X is a ridge formed last. With the use of a spoon and hammer or mallet, place the spoon on the ridge and strike it with the hammer. Aim your hammer blows directly at the ridge. By following the ridge with the spoon and hammer, you will find that the ridge will gradually disappear while the major portion of the depression at Y will spring back and very closely resemble the original contour of the panel.

The next step is to select a dolly block with a face of the same general curvature as the panel. Place it under the panel at 0 and strike the dent as illustrated with the dolly. In this way, the dolly acts as a hammer and raises the dented portion to the original contour as the dolly is gradually moved toward point Z. The most common mistake made by the beginner at this point is trying to do all the work with one blow of the dolly. All that is necessary of the hammer or dolly is to press the metal back into position. A number of light blows with the hammer is better than a few heavy ones. Heavy hammer blows result in the metal stretching excessively during the straightening process. This requires that the panel be shrunk later to remove bulges.

When working with the hammer, apply blows rapidly with a pulling action so the hammer tends to slide as it contacts the metal. Above all, don't try to rush the job by striking the metal too heavily. Figures 9-52 and 9-53 illustrate the procedures for removing dents when performing body work. Use of a flat-faced hammer should be confined to the flat or nearly flat surfaces and the outside of curved surfaces. Hammers with crowned faces are for use on concave surfaces only.

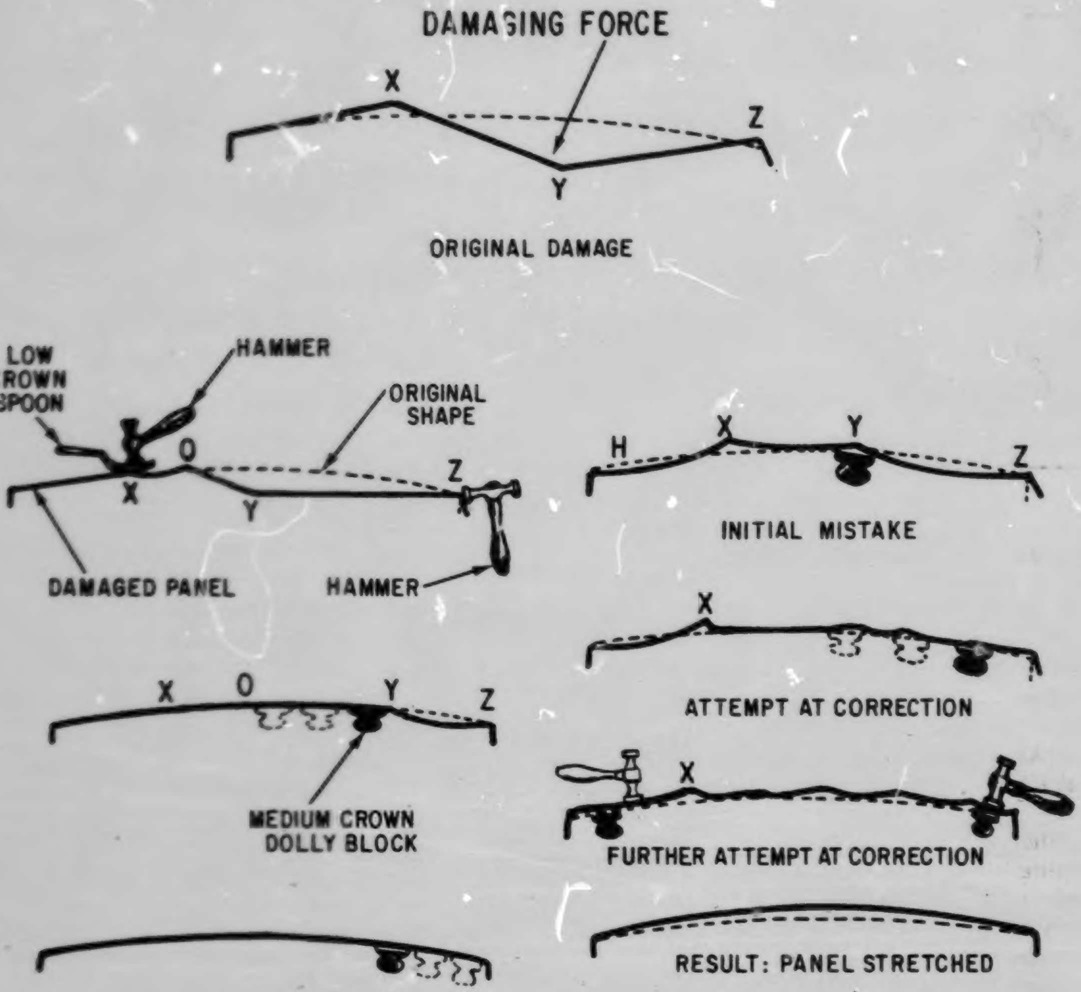
REPLACING SHEET METAL

Generally, a severaly damaged panel will be replaced or repaired by cutting out the damaged portion and replacing it with sheet metal. Should you receive instructions to repair a heavily damaged body panel, there are a few things that should be considered before starting the job.

The first and most important consideration is to determine the direction of the force that caused the damage. This will enable you to use the hydraulic jack and its attachments to push the panels back into a near original position. At the same time, the braces holding the sheet metal will move back to their original position and allow access to any bolts and fastening devices that must be removed to disassemble the damaged body parts. Once you have reached this point, it must be determined if the damaged panels will be replaced or repaired.

Should you elect to replace the damaged panel, make sure any braces that support the panel are ordered also. New braces will help to aline the new panels with the rest of the body. Should only a portion of the damaged area be replaced, a welding outfit (fig. 9-54) will be needed to weld the new sheet metal into position. Complete instructions on the use and care of gas cutting and welding equipment are contained in the current edition of *Steelworker 3 & 2,* NAVEDTRA 10653 series. Before attempting to replace body panels, consult this manual for the proper method of adjusting and using the cutting or welding tips.

Once the section of the panel you want replaced is cut away and the remaining portion straightened to the original contour, place a piece of the sheet metal over the area that is cut away. Mark the new sheet metal so that when you cut on the lines drawn, the piece will be slightly larger than the area being replaced. Clamps are needed to hold the new piece of sheet metal in position for welding. Use the


DAMAGING FORCE
X
Z
Y
ORIGINAL DAMAGE
LOW CROWN SPOON
HAMMER
ORIGINAL SHAPE
O
X
Y
Z
DAMAGED PANEL
HAMMER
H
X
Y
Z
INITIAL MISTAKE
X
ATTEMPT AT CORRECTION
X
O
Y
Z
MEDIUM CROWN DOLLY BLOCK
X
FURTHER ATTEMPT AT CORRECTION
RESULT: PANEL STRETCHED

WHEN REPAIRS ARE STARTED CORRECTLY, THE DENTS DISAPPEAR QUICKLY

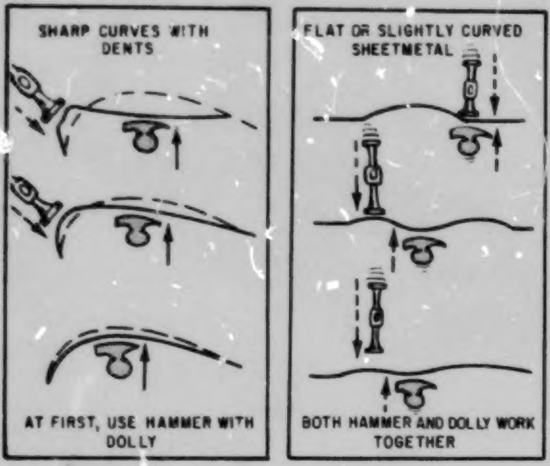
STARTING THE REPAIR WORK AT THE WRONG PLACE WILL RESULT IN PROBLEMS LATER

81.580

Figure 9-51.—Finding the right starting point is very important when performing body repairs.

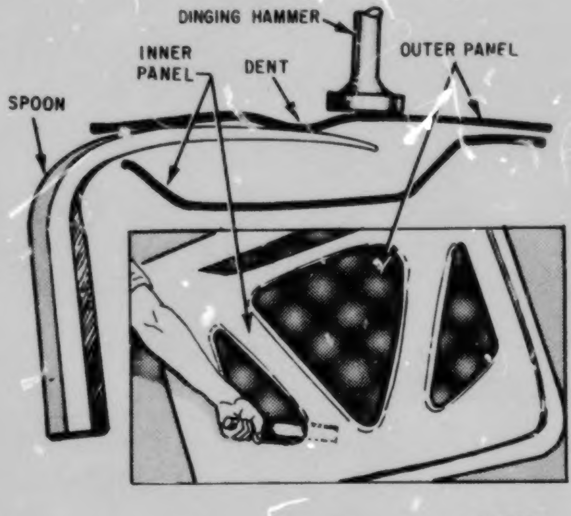
same method to weld a new section as in that used for repairing cracks (fig. 9-55). Once the piece is welded, the weld should be ground down with a disk sander. While operating the sander, use care not to cut through the sheet metal with the heavy grit paper. A few passes with the sander (fig. 9-56) will quickly show up any high places in the metal that must be shrunk or the low spots.

Figure 9-57 illustrates the procedure for shrinking sheet metal. Only a small area at a time is heated and shrunk. This will cause a


SHARP CURVES WITH DENTS
AT FIRST, USE HAMMER WITH DOLLY
FLAT OR SLIGHTLY CURVED SHEETMETAL
BOTH HAMMER AND DOLLY WORK TOGETHER

81.581

Figure 9-52.—Arrow indicates direction metal must move to return to original contour.


DINGING HAMMER
INNER PANEL
DENT
OUTER PANEL
SPOON

81.582

Figure 9-53.—The spoon can be used as both a lever and dolly when working in tight places.

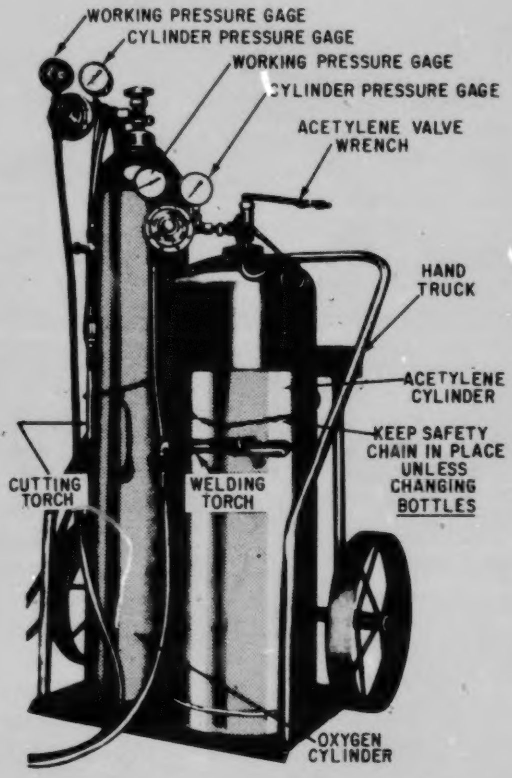
panel to return to its original contour when performed properly.

PREPARING THE SURFACE FOR PAINTING

Whether the surface being prepared for painting is just a small repair on a fender or the whole vehicle is to be painted, the following procedures should be followed. It is essential that you prepare the surface for the paint by removing all traces of wax, grease, oil and dirt. If the paint on the vehicle is of poor quality or seriously deteriorated, it should be removed. Different grits of sandpaper are available for your use in preparing the old surface. Generally, start with the heavy grit (coarse) and work to the lighter (fine). This will speed up your work and provide a smooth surface for the primer coat. Once the sanding is completed, clean the surface with a cleaning agent. If none is available, a lint free cloth saturated with thinner can be used to wipe down the surface. This will help the new paint to adhere to the metal and remove the dust and other foreign matter.

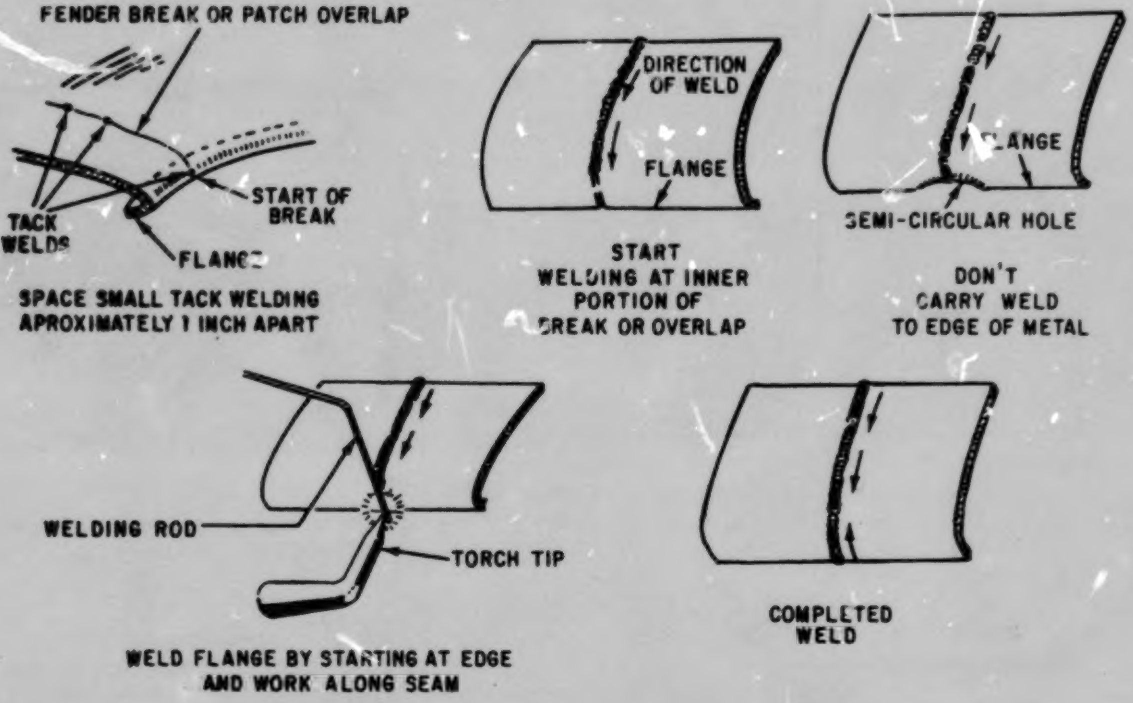
PAINTING

Navy vehicles are painted with enamel that must conform to specifications. Exceptions to


WORKING PRESSURE GAGE
CYLINDER PRESSURE GAGE
WORKING PRESSURE GAGE
CYLINDER PRESSURE GAGE
ACETYLENE VALVE WRENCH
HAND TRUCK
ACETYLENE CYLINDER
KEEP SAFETY CHAIN IN PLACE UNLESS CHANGING BOTTLES
CUTTING TORCH
WELDING TORCH
OXYGEN CYLINDER

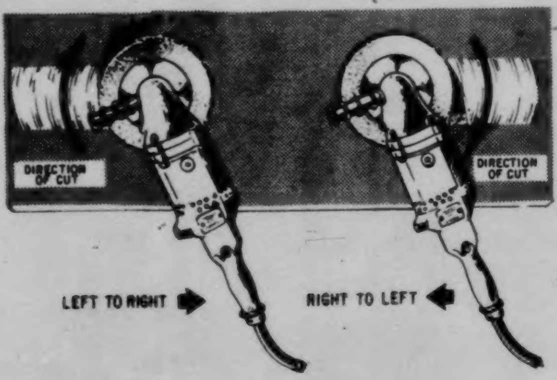
127.368

Figure 9-54.—Oxyacetylene welding outfit.


FENDER BREAK OR PATCH OVERLAP
TACK WELDS
START OF BREAK
FLANGE
SPACE SMALL TACK WELDING APROXIMATELY 1 INCH APART
DIRECTION OF WELD
FLANGE
START WELDING AT INNER PORTION OF BREAK OR OVERLAP
FLANGE
SEMI-CIRCULAR HOLE
DON'T CARRY WELD TO EDGE OF METAL
WELDING ROD
TORCH TIP
WELD FLANGE BY STARTING AT EDGE AND WORK ALONG SEAM
COMPLETED WELD

81.583

Figure 9-55.—Follow direction of arrows when repairing fender breaks or replacing sheet metal.


DIRECTION OF CUT
DIRECTION OF CUT
LEFT TO RIGHT
RIGHT TO LEFT

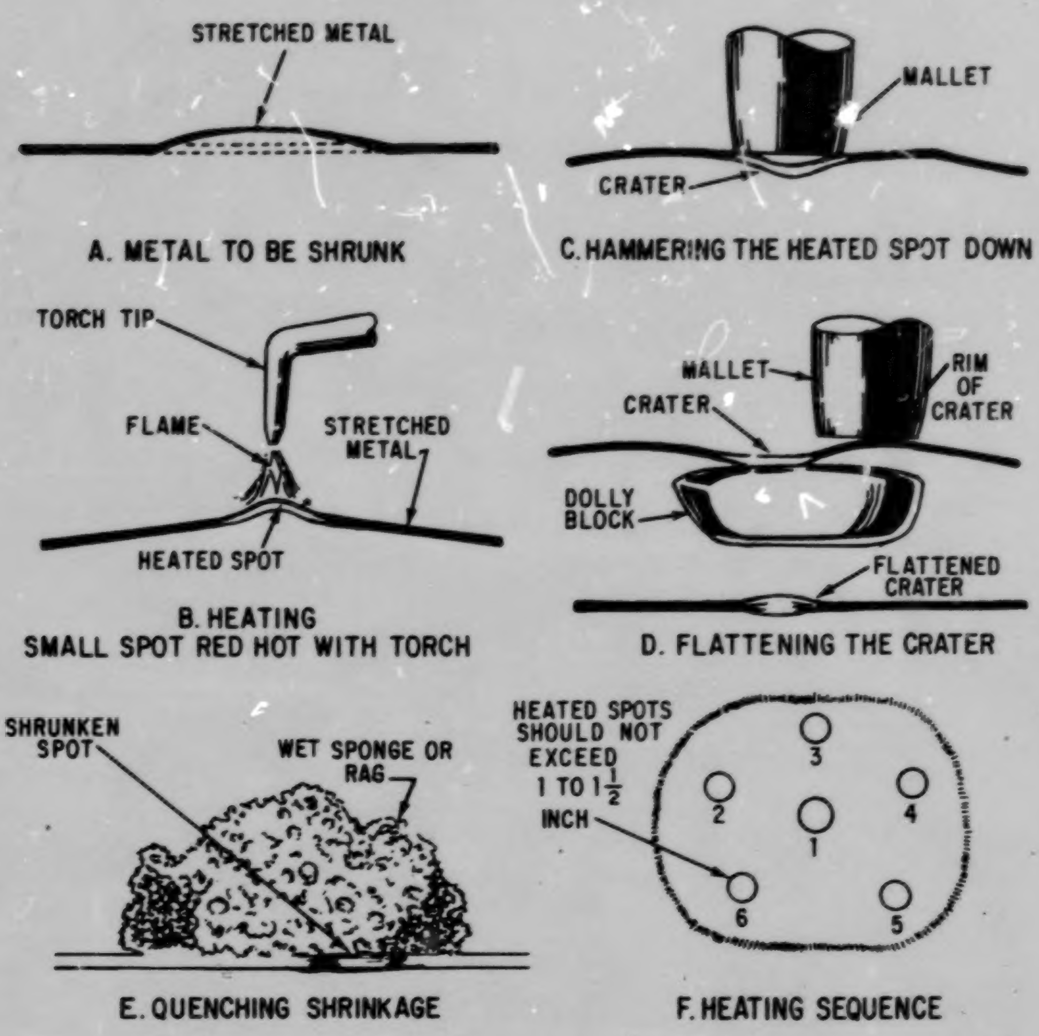
81.584

Figure 9-56.—Exercise care while sanding with a disk sander to prevent burning or cutting holes in the thin sheet metal.

this is usually found on vehicles that are painted by the manufacturer prior to delivery to the government. Colors you are authorized to use when painting vehicles and equipment assigned to the Naval Construction Force are:

Red	Number	11105
Yellow	"	13538
Green	"	14064
Black	"	17038
White	"	17875

Prior to the use of these paints, a coat of primer should be applied to prevent peeling and flaking where the bare metal is exposed. The primer serves as a bond between the paint and the metal of the vehicle. Each coat that is applied must be sanded LIGHTLY if allowed to dry before applying the next coat. There may be


STRETCHED METAL
A. METAL TO BE SHRUNK
MALLET
CRATER
C. HAMMERING THE HEATED SPOT DOWN
TORCH TIP
FLAME
STRETCHED METAL
HEATED SPOT
B. HEATING SMALL SPOT RED HOT WITH TORCH
MALLET
CRATER
RIM OF CRATER
DOLLY BLOCK
FLATTENED CRATER
D. FLATTENING THE CRATER
SHRUNKEN SPOT
WET SPONGE OR RAG
E. QUENCHING SHRINKAGE
HEATED SPOTS SHOULD NOT EXCEED 1 TO 1½ INCH
1
2
3
4
5
6
F. HEATING SEQUENCE

81.585

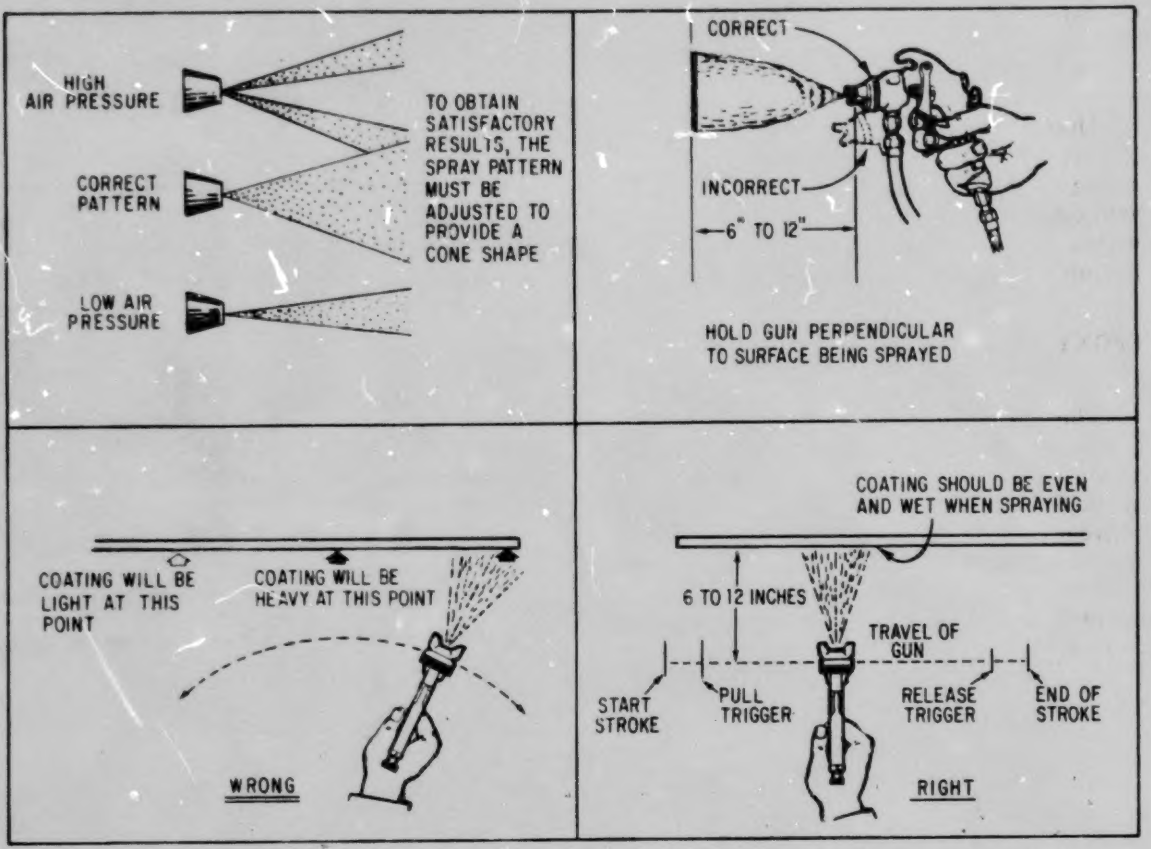
Figure 9-57.—Metal shrinking process and sequence used for large areas.

occasion to use two coats of primer, but normally, one coat is adequate.

Paint and primer must be shaken or stirred thoroughly, thinned with a thinning agent, and run through a strainer or filter if a spray gun is used. Figure 9-58 illustrates the method for use of the spray gun.

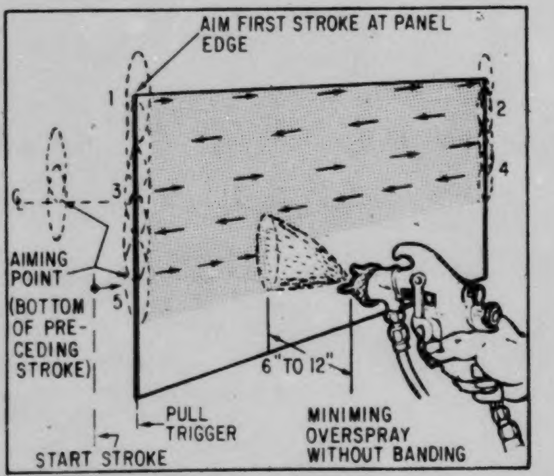
The amount of thinner to add depends on the type of paint. Some paint or thinner containers have directions on the outside while other do not. If you cannot locate them, see your supervisor for assistance.

Another ingredient that is sometimes added to paint is "drier." This substance causes the paint to set and dry much more rapidly than


HIGH AIR PRESSURE
CORRECT PATTERN
LOW AIR PRESSURE
TO OBTAIN SATISFACTORY RESULTS, THE SPRAY PATTERN MUST BE ADJUSTED TO PROVIDE A CONE SHAPE
CORRECT
INCORRECT
6" TO 12"
HOLD GUN PERPENDICULAR TO SURFACE BEING SPRAYED
COATING WILL BE LIGHT AT THIS POINT
COATING WILL BE HEAVY AT THIS POINT
WRONG
COATING SHOULD BE EVEN AND WET WHEN SPRAYING
6 TO 12 INCHES
TRAVEL OF GUN
START STROKE
PULL TRIGGER
RELEASE TRIGGER
END OF STROKE
RIGHT

HOLDING AND MOVING THE SPRAY GUN CORRECTLY IS AS IMPORTANT AS THE SPRAY PATTERN

NOTE:
DIFFERENT TYPES OF PAINT REQUIRE DIFFERENT AIR PRESSURES FOR SPRAY APPLICATION


AIM FIRST STROKE AT PANEL EDGE
1
2
3
4
5
6
7
AIMING POINT (BOTTOM OF PRECEDING STROKE)
6" TO 12"
PULL TRIGGER
START STROKE
MINIMING OVERSPRAY WITHOUT BANDING

OVERLAPPING SUCCESSIVE STROKES PROVIDES AN EVEN COAT OF PAINT

OVERLAPPING EACH PASS

81.586

Figure 9-58.—Follow these basic steps to a professional finish.

normal. Because a small amount of drier is all that is needed, the instructions on its use must be followed closely.

Mixing paint and adding drier are two critical parts of painting vehicles. Use of the wrong type of thinner, paint, or excessive drier will cause the paint to fade, peel, or blister within a short period of time after completing the job.

EPOXY FILLERS

The modern auto body repair shop would not be caught without a bunch of this stuff on hand. Your being in the Navy, and particularly in the SEABEES, prevents you from having this convenient item unless it is purchased through special order or open purchase. Shelf life of the item (length of time it can be stored before use) is not long enough for the supply department to carry it in stock.

You may find body fillers used in a Public Works repair shop. Its use is simple in that the body portions do not have to be straightened as closely as when making repairs without it. Some fillers require that a primer coat of paint be applied over the metal prior to their application while others do not. By using the manufacturer's instructions, you can apply body filler over rough places and form it with a body file or sanding until it conforms to the contour desired. The advantage of using body filler lies in the fact that a badly damaged vehicle can be returned to a like new appearance quickly and with only a limited amount of metal straightening. Additionally, the use of thinner metal in the bodies of modern vehicles makes it difficult to reform panels into their original shape. Should you have an opportunity to use an epoxy filler, the recommended thickness of the filler should be kept to approximately 1/8″. If more is required, it should be applied in coats not to exceed 1/4″ and allowed to dry before applying the next coat.

CHAPTER 10

BRAKES

Good brakes are an absolute necessity for the safe operation of all self-propelled vehicles and equipment. The emphasis of manufacturers on speed and hauling capacity results in an ever increasing demand for improvements in braking systems. The brakes must not only be able to stop the equipment, but also must do so reliably and in as short a distance as possible. In order to provide the proper service and repair to these braking systems, the mechanic must have a good understanding of how these systems function. Improper repairs can result in a fatal accident if brakes fail to function properly.

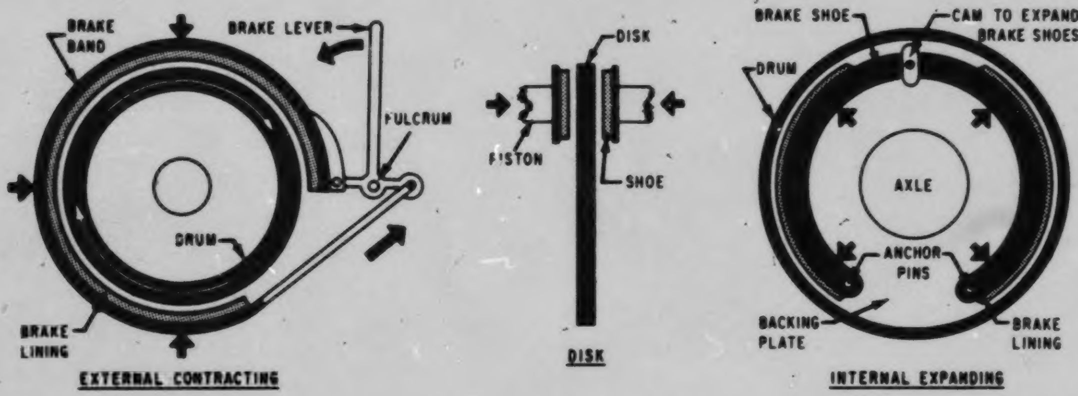
Brake operation is dependent on the friction created when two surfaces (one stationary and one moving) are brought into contact with each other. In brake systems, brake drums or disks provide the moving surface and brake shoes or bands the stationary surface. Thus the wheels or other moving componenets connected to the drums or disks will slow, stop, or remain stationary, when the brakes are applied (fig. 10-1).

TYPES OF BRAKES

Two types of brakes are provided on all self-propelled equipment: the parking brake, used for keeping the equipment stationary when stopped, and the service brakes that are used during normal stop and go operation.

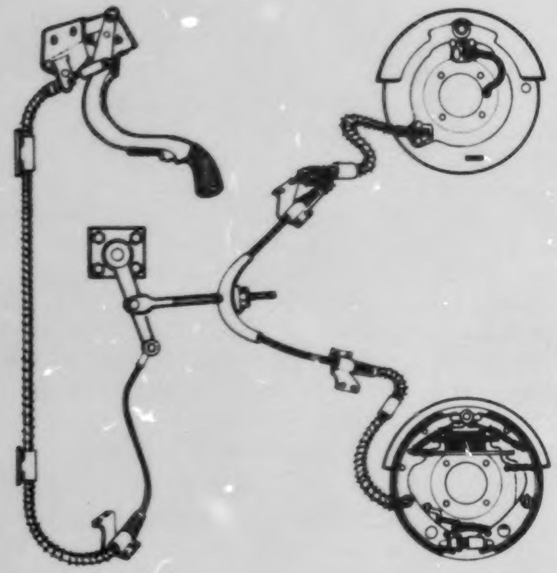
PARKING BRAKES

Parking brakes on the majority of light-duty vehicles are interconnected with the service brakes at the rear of the vehicle (fig. 10-2).


BRAKE BAND
BRAKE LEVER
FULCRUM
DRUM
BRAKE LINING
EXTERNAL CONTRACTING
DISK
PISTON
SHOE
DISK
BRAKE SHOE
CAM TO EXPAND BRAKE SHOES
DRUM
AXLE
ANCHOR PINS
BACKING PLATE
BRAKE LINING
INTERNAL EXPANDING

81.273:275

Figure 10-1.—Methods of brake application.



81.458

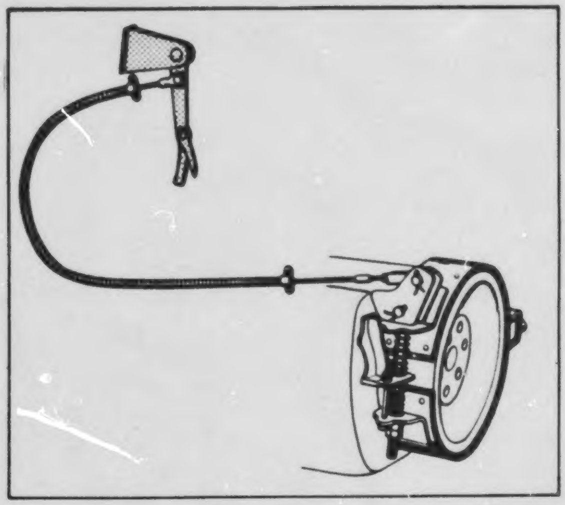
Figure 10-2.–Typical parking brake (integral type).

Heavy-duty parking brakes are usually mounted at the rear of the transmission or transfer case (fig. 10-3). An adjustment is provided in the linkage of both types to compensate for lining wear. The lining of the integral type is replaced when the service brakes are repaired. The transmission type parking brake is serviced separately when the lining has worn a predetermined amount.

SERVICE BRAKES

Service brakes are normally provided at each wheel and function when a pedal is depressed by the operator. Except in the case of some track mounted equipment, service brakes depend on hydraulic fluid or air as a medium for applying the brakes.

In this chapter, the discussion concerning service brakes will be divided into two major sections, HYDRAULIC BRAKES and AIR BRAKES.

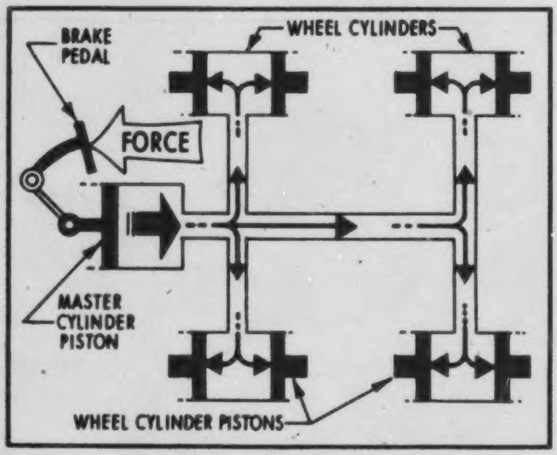


81.457

Figure 10-3.–Typical parking brake (external band transmission type).

HYDRAULIC BRAKES

Hydraulic brakes use liquid as a connection or coupling between the brake pedal and the service brakes, as indicated in figure 10-4. This liquid (brake fluid) will not freeze or boil unless



81.280

Figure 10-4.–Diagram of the operation of a hydraulic brake system.

subjected to extreme temperatures. Brake fluid other than that obtained through normal supply channels should be labeled either DOT-3, J1703A, or J1703. All these fluids are suitable for use with both drum and disk brakes.

MASTER CYLINDERS

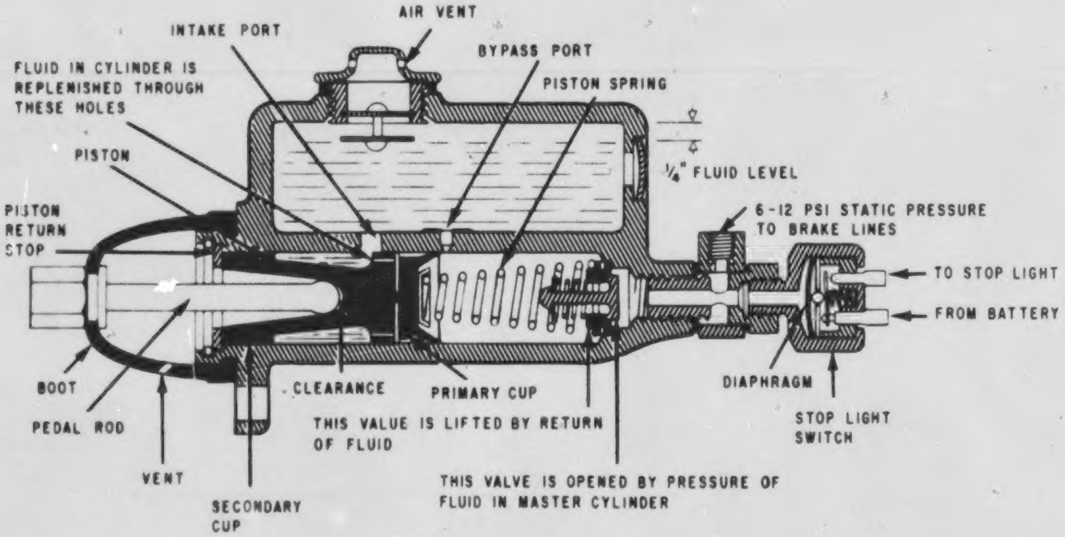
Master cylinders (fig. 10-5, 10-6 and 10-7) are designed for use with single or dual braking systems. These cylinders contain one or two fluid reservoirs and pistons which force the fluid through the lines into the wheel cylinders. As pressure on the pedal is increased, greater pressure is built up within the brake cylinders, and thus greater force is applied to the brake shoes. When pressure on the pedal is released, the springs on the brake shoes return the wheel cylinder pistons to their released positions. This action forces the brake fluid back to the master cylinder. There is also a return spring in the master cylinder and at the brake pedal.

Master cylinders used with drum brakes often contain a residual check valve which retains a slight pressure within the lines and wheel cylinders when the brakes are released. This pressure prevents fluid from seeping past the cups in the wheel cylinders and also prevents the entrance of air into the hydraulic passages as the brakes are released.

Dual master cylinders contain two of everything found in the master cylinder used for single systems. Thus, these cylinders provide separate pressure systems, one for the front brakes and one for the rear. These cylinders provide an additional safety feature in that should one portion of the brake system fail, the other will continue to function. However, should one portion of the system fail, brake pedal travel will increase noticeably.

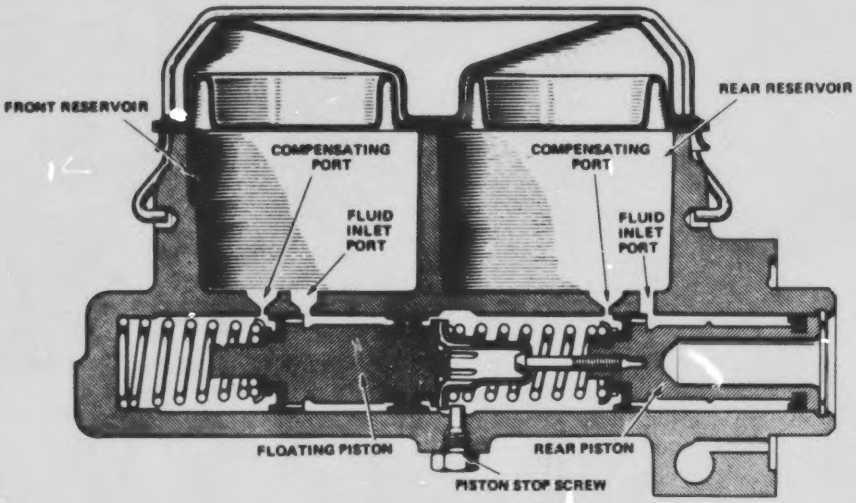
Dual system master cylinders for disk brake applications are practically the same as other dual system master cylinders, except that the fluid reservoir for the disk brakes is much larger than the reservoir for the drum brakes. In addition, the output port to the disk brakes does not contain a residual pressure check valve.

The shoes of disk brakes are always in slight contact with the disk and when the brake is


INTAKE PORT
AIR VENT
BYPASS PORT
FLUID IN CYLINDER IS REPLENISHED THROUGH THESE HOLES
PISTON SPRING
PISTON
¼" FLUID LEVEL
PISTON RETURN STOP
6-12 PSI STATIC PRESSURE TO BRAKE LINES
TO STOP LIGHT
FROM BATTERY
BOOT
CLEARANCE
PRIMARY CUP
DIAPHRAGM
PEDAL ROD
THIS VALUE IS LIFTED BY RETURN OF FLUID
STOP LIGHT SWITCH
VENT
SECONDARY CUP
THIS VALVE IS OPENED BY PRESSURE OF FLUID IN MASTER CYLINDER

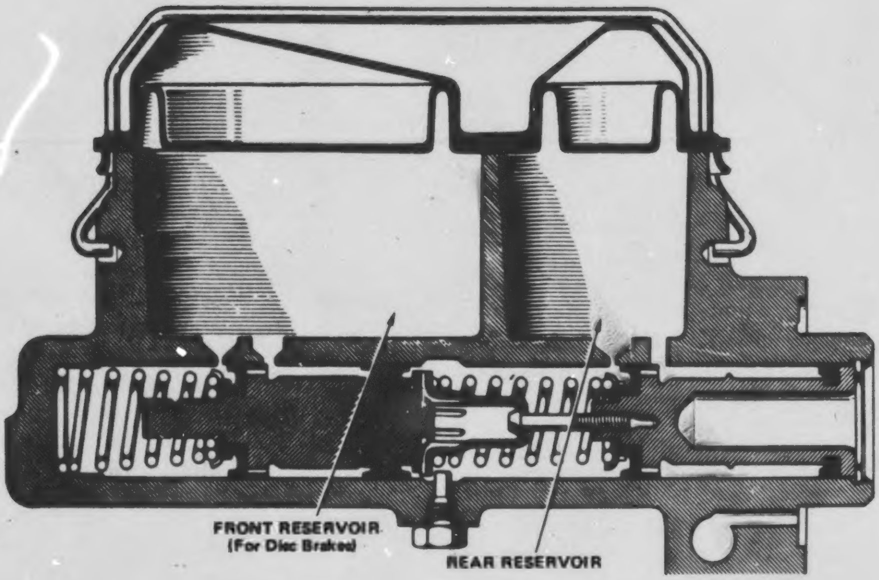
81.555

Figure 10-5.—Cutaway view of master cylinder.


FRONT RESERVOIR
REAR RESERVOIR
COMPENSATING PORT
COMPENSATING PORT
FLUID INLET PORT
FLUID INLET PORT
FLOATING PISTON
REAR PISTON
PISTON STOP SCREW

2.421

Figure 10-6.–Dual system master cylinder.


FRONT RESERVOIR
(For Disc Brakes)
REAR RESERVOIR

2.423

Figure 10-7.–Dual system master cylinder for disk brakes.

applied, no appreciable amount of fluid is forced into its cylinder. The larger reservoir is necessary because as the shoes wear, they move outward, creating a larger cavity in the caliper cylinder and fluid moves from the master cylinder to fill the additional area.

Master cylinder reservoir fluid level should be checked periodically and clean brake fluid added, as needed, to maintain fluid level approximately 1/4 inch from the top of the reservoir.

When major brake service is being performed, the master cylinder should be reconditioned or replaced as necessary. Often the master cylinder bore can be cleaned with crocus cloth or a master cylinder hone. When it is badly scored, pitted, or corroded, however, the master cylinder should be replaced.

After you clean up a master cylinder bore, be sure you check the clearance between the cylinder bore wall and piston. If a narrow (1/8" to 1/4" wide) 0.006" feeler gage can be inserted between the cylinder wall and a new piston, the master cylinder should be replaced. Be careful when inserting the feeler gage between the piston and cylinder wall to avoid damaging cups on the piston.

When servicing a master cylinder, be careful to keep all parts clean and free from mineral oil and grease. Do not handle hydraulic system parts with oily or greasy hands.

It is good practice to bench bleed a new or reconditioned master cylinder before installing it on a vehicle. This is particularly true of the dual system master cylinders. Bench bleeding removes any air from the master cylinder bore and saves time when you are bleeding the balance of the hydraulic system.

BRAKE FLUID DISTRIBUTION

The brake lines transmit fluid and pressure to the wheel cylinders or disk brake calipers. In addition to the steel tubing, flexible reinforced rubber hoses are used at the rear axle and both front wheels. On vehicles equipped with full independent suspension, flexible hoses are also used on both rear wheels.

The steel lines seldom need replacement except in areas where they rust from exposure to salt air or constant high humidity. If you replace them, you should ALWAYS use steel tubing. The flexible hoses should be inspected at regular maintenance periods for any signs of cracking or abrasion. If the outer protective cover is cracked or badly abraded, it should be replaced.

A pressure actuated brake light switch is used in the single system. This switch may be found at the master cylinder or elsewhere in the distribution system. In dual brake applications, the switch is mechanically actuated by brake pedal linkage when the brake pedal is depressed.

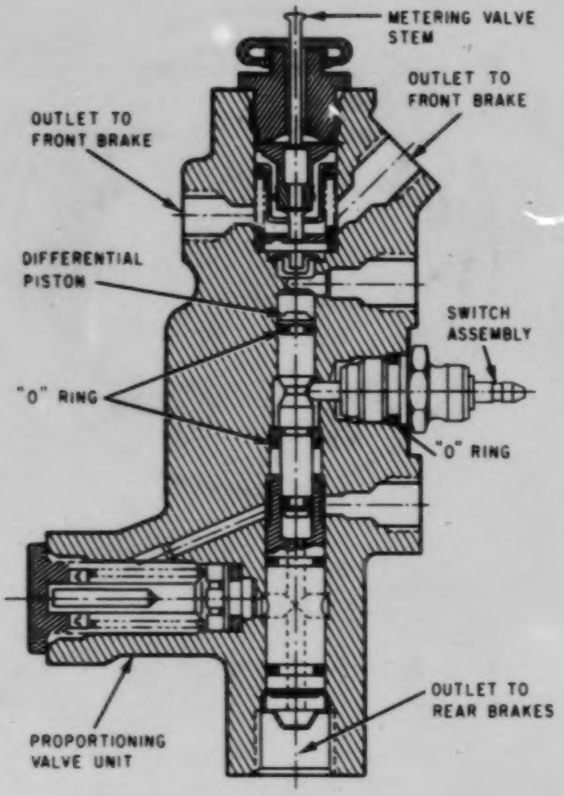
In addition to the components contained in the single system, the dual system contains a brake warning light switch. If the system is equipped with front disk brakes, a proportioning valve and metering valve are also added. These components may be separate or in one assembly, as illustrated in figure 10-8.

The warning light switch operates a light on the instrument panel to signal the operator should the front or rear brake system fail.

In some applications special procedures are required to recenter the differential piston in the valve body and prevent constant operation of the warning light after the brake system has been repaired.

The proportioning valve is actuated by pressure in the rear drum portion of the brake system, and prevents skidding during heavy braking. The metering valve operates in conjunction with the disk portion of the brake system. This valve functions during the intitial stage of brake application to prevent excessive front disk braking until the rear drum brakes overcome return spring pressure and contact the drums.

To determine if either of these valves is faulty, carefully follow the manufacturer's procedures contained in the service manual. No attempt should be made to repair the switch or valves should they be inoperative.

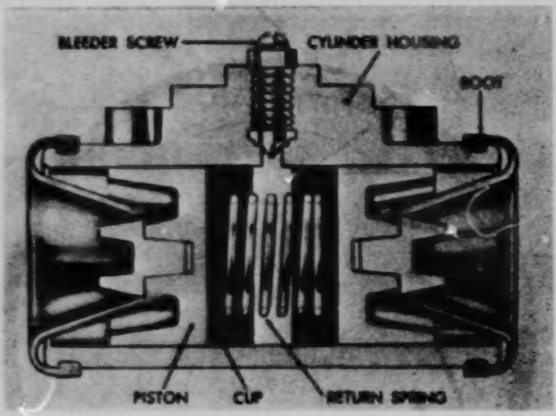

METERING VALVE STEM
OUTLET TO FRONT BRAKE
OUTLET TO FRONT BRAKE
DIFFERENTIAL PISTON
SWITCH ASSEMBLY
"O" RING
"O" RING
OUTLET TO REAR BRAKES
PROPORTIONING VALVE UNIT

81.556
Figure 10-8.–Combination valve.

WHEEL CYLINDERS

Wheel cylinders used with drum brakes on the majority of self-propelled equipment are similar to the one illustrated in figure 10-9. With this cylinder, fluid pressure causes both pistons to move outward in the cylinders and apply force to the brake shoes. Return springs, attached to the shoes, cause the shoes and cylinder pistons to return to their original position when the brakes are released.

Normally, faulty wheel cylinders are detected when fluid leaks appear or the pistons stick in the cylinders, preventing brake application. Should this occur, repair procedures are similar to those outlined previously for master cylinders.


BLEEDER SCREW
CYLINDER HOUSING
BOOT
PISTON
CUP
RETURN SPRING

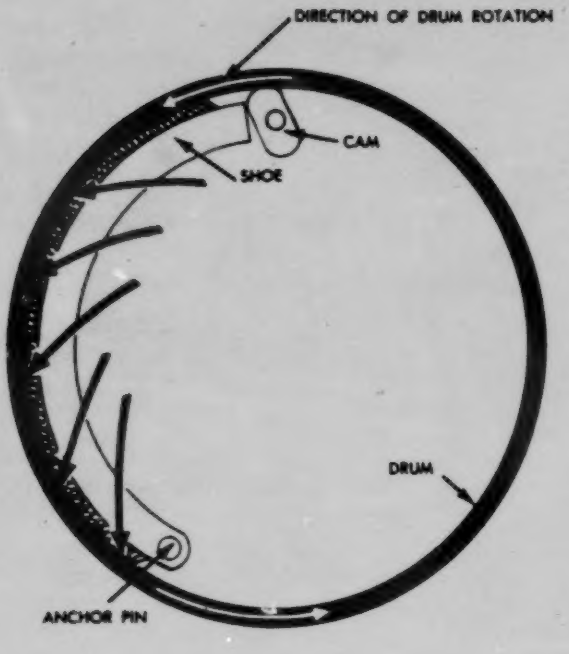
81.282
Figure 10-9.–Cross section of a wheel cylinder.

DRUM BRAKE ASSEMBLIES

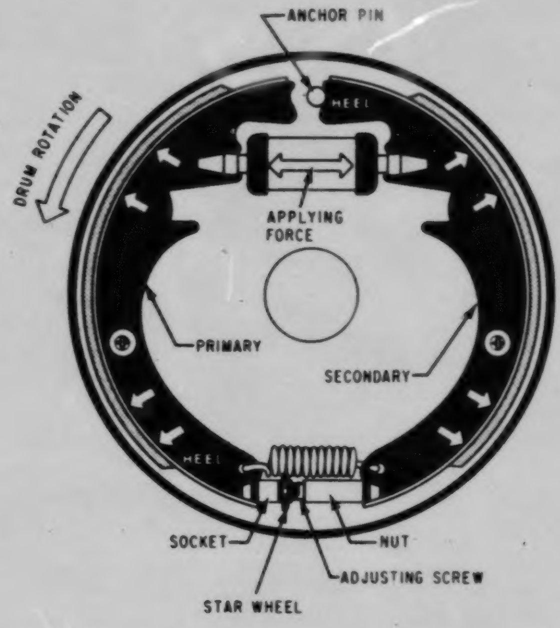
Internal expanding drum brakes are the most common type of brake used on self-propelled equipment. These brakes depend on a "self-energizing" (servo) action to supplement the effort provided by the operator. The term "self-energizing" describes the action of the shoes once they contact the moving drum.

When one end of the shoe is attached to a stationary pin (fig. 10-10), the shoe will tend to rotate with the drum and wedge between the anchor pin and drum. This wedging action increases the braking effect initiated by the cam. When two shoes are independently anchored at the bottom of the backing plate, the other shoe has a tendency to move away from the drum and provide far less braking effort. Should the drum turn in the opposite direction, the self-energizing action would affect the operation of the second brake shoe (not shown).

When both shoes are interconnected (full-floating) and attached to the backing plate



81.277
Figure 10-10.—Brake shoe self-energizing action.



81.557
Figure 10-11.—Full-floating brake assembly.

in such a manner that they both tend to move with the drum, "self-energizing" action will affect both shoes (fig. 10-11). In these applications, the self-energizing action of the primary (leading) shoe is transmitted to the secondary (trailing) shoe. Both shoes will be wedged against the drum. This arrangement provides the self-energizing action to both shoes regardless of direction of travel.

Most drum brakes used on automotive and light-duty vehicles have a self-adjusting mechanism (fig. 10-12). This device adjusts the brakes to compensate for lining wear. This mechanism operates only in reverse.

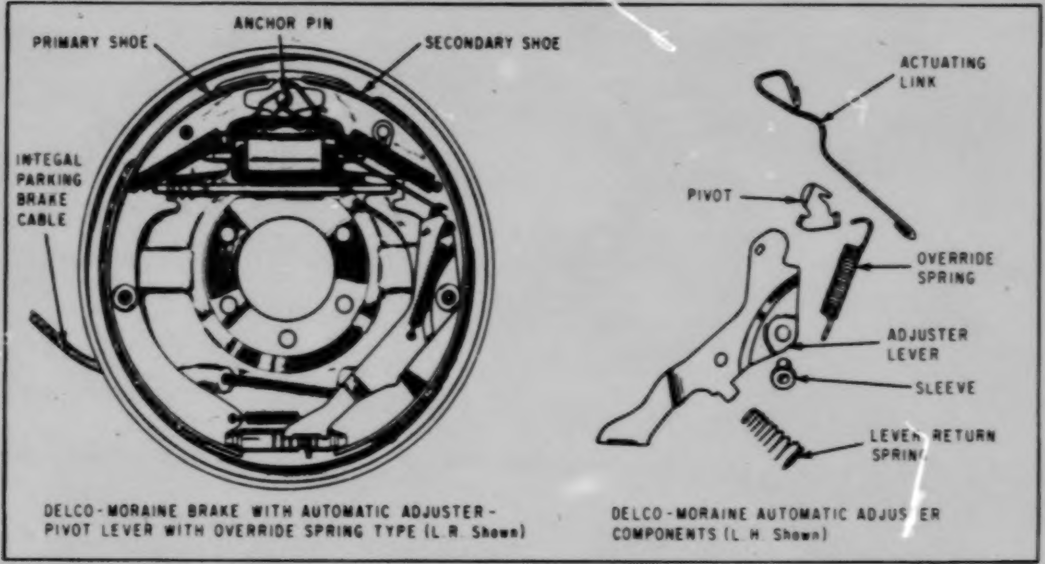
When the vehicle is moving backward and the brakes are applied, friction causes the secondary shoe to move away from the anchor pin. Since the upper end of the adjusting lever is held stationary by the actuating link, the lever pivots on the secondary shoe, and its lower end acts on the adjusting screw sprocket (starwheel). If the linings are worn enough to permit the secondary shoe to move a predetermined distance, the adjuster lever will turn the adjusting screw one tooth. This causes the shoes to expand only a few thousandths of an inch. When the brake is released, the lever return spring will lift the adjuster lever into the adjusting position on the sprocket.

An override feature is provided to allow brake action by the secondary shoe in the event the adjusting screw becomes "frozen," or the self-adjuster becomes inoperative.

When the vehicle is moving forward and the brakes are applied, the secondary shoe is held against the anchor pin by the self-energizing action of the brakes, preventing the self-adjuster from functioning.

DRUM BRAKE SERVICE

Servicing drum brake assemblies involves periodic adjustment (unless self-adjusting),


ANCHOR PIN
PRIMARY SHOE
SECONDARY SHOE
INTEGAL PARKING BRAKE CABLE
ACTUATING LINK
PIVOT
OVERRIDE SPRING
ADJUSTER LEVER
SLEEVE
LEVER RETURN SPRING
DELCO-MORAINE BRAKE WITH AUTOMATIC ADJUSTER-PIVOT LEVER WITH OVERRIDE SPRING TYPE (L.R. Shown)
DELCO-MORAINE AUTOMATIC ADJUSTER COMPONENTS (L.H. Shown)

81.456

Figure 10-12.—Automatic brake adjuster.

replacement of the linings when worn excessively or unserviceable, and resurfacing the brake drums when required.

Adjusting

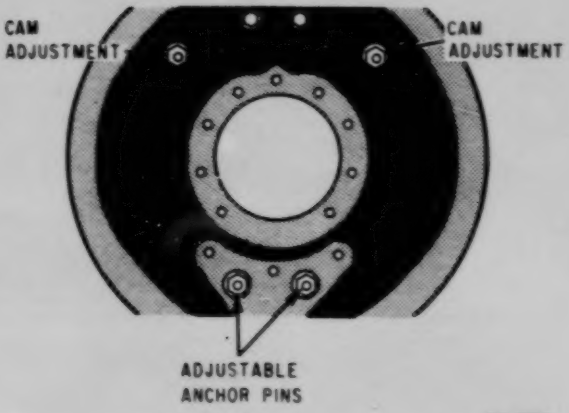
The procedures for adjusting drum brakes depend on the particular application. In most applications having independently attached shoes, two adjustments are provided at the rear of the backing plate (fig. 10-13). The anchor pins are of an eccentric design and are used to position the heel of the shoes in relation to the drum only when the shoes and/or linings are replaced. The cam adjusting bolts located at the top of the backing plate are adjusted to position the toe of the brakeshoe when the shoes and/or linings are replaced. The cam adjusting bolts are also used to adjust the brakes when the linings wear from normal use.

Full floating brakes (fig. 10-11) are adjusted by inserting a thin bladed tool through a slot in the backing plate behind the starwheel. Brakes with this type of adjustment require you to turn the starwheel until the wheel is locked by the brake shoes and then back off the starwheel a certain number of notches.

Regardless of the application, unless thoroughly familiar with the type you are adjusting, you should follow the procedures outlined in the manufacturer's service manual.

Replacing Drum Brake Linings

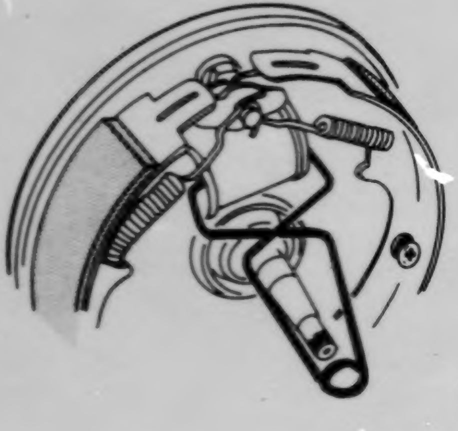
In order to replace the brake shoes on drum brakes, the wheel and drum must be removed


CAM ADJUSTMENT
CAM ADJUSTMENT
ADJUSTABLE ANCHOR PINS

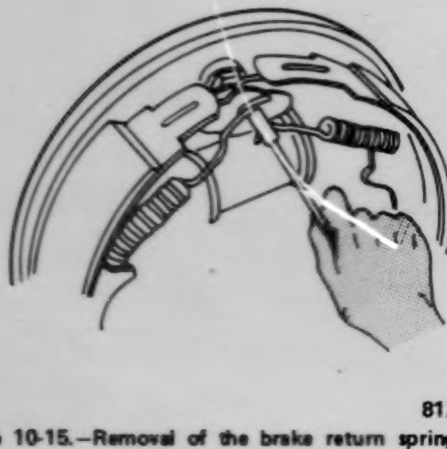
81.558

Figure 10-13.—Brake adjustments.

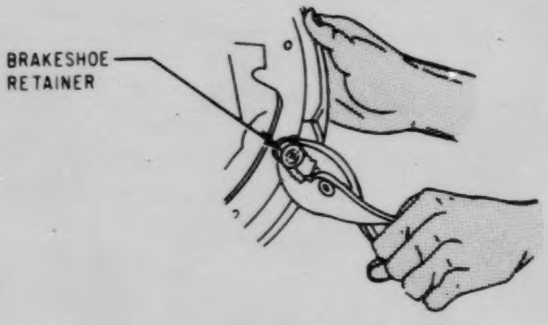
first. Notice carefully how the springs and retainers are installed before attempting to remove the shoes from the backing plate. This will assist you during reassembly. If hydraulic brakes are being repaired, install a wheel cylinder clamp (fig. 10-14) or tie the cylinder to keep the pistons from coming out of the wheel cylinder once the brake shoes are removed. Next, remove the retracting springs with brake spring pliers or a removal and installation tool as shown in figure 10-15. The shoe holddown parts must be removed next. Figure 10-16 illustrates one type being removed with a pair of ordinary combination pliers. Heavy-duty brake shoes are mounted on separate anchor pins. Some of these installations require removal of the anchor pins, while others require the removal of clips on the end of these pins before the shoes can be removed. On light-duty brake applications, you can now grasp the shoes as shown in figure 10-17 and remove them. After removing, turn the shoes as shown in figure 10-18. This allows easy removal of the spring and adjusting screw assembly.



81.559
Figure 10-14.—Wheel cylinder clamp in use.

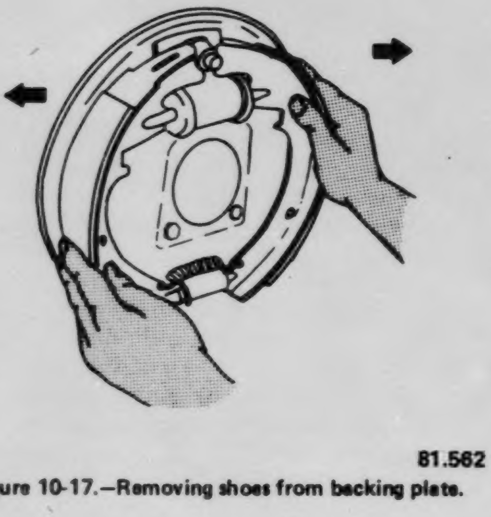


81.560
Figure 10-15.—Removal of the brake return springs is easy if you use the proper tool.

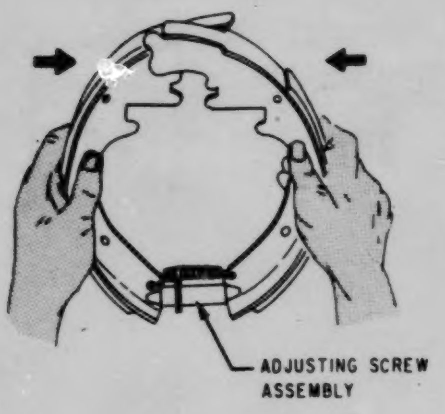


81.561
Figure 10-16.—The brake shoe retainer causes the shoe to contact the drum squarely as the brakes are applied.

Mark the front and rear shoe of each brake so that they may be replaced in the same



81.562
Figure 10-17.—Removing shoes from backing plate.



81.563

Figure 10-18.–Removing adjusting screw assembly.

position. Clean the backing plate thoroughly and apply a light coating of lubricant to the backing plate where the shoes are supported.

New linings are secured to the shoes by rivets or bonding after the old lining and rivets have been removed. Bonded brake linings are supplied with the linings already attached to the shoes. At some activities, the old shoe assemblies must be exchanged when drawing new ones from the parts room. Linings that require the use of rivets to attach the linings to the shoes are provided in kits. These kits may provide enough linings for one or more wheels and the rivets needed for attaching them to the shoes. These linings are predrilled and countersunk for the rivets and arced to match the brake shoes.

Should your shop have the specialized equipment for relining brakes, it should be used to remove and replace the riveted linings. If this equipment is not available, the old linings can be removed with a suitable punch and hammer if care is exercised to prevent enlarging the rivet holes in the shoes. If the rivet holes are enlarged, the shoe should be discarded.

The NMCB shops now use a vise held device for installing the rivets. This device comes with adapters for use with various size rivets and is stored in the shop's tool room. When installing rivets, always start in the center of the lining and work alternately to each end of the lining. Make sure that the rivets are tight enough to securely hold the lining without splitting the lining at the rivet holes. Once the linings are attached to the shoes, reassemble the brakes by reversing the method of removal.

Servicing Brake Drums

After you remove the drums, inspect the old shoes to determine the drums' condition. For instance, if the linings are worn thin on one side, the drums are likely to be tapered or bell shaped. Linings with ridges in their contact surfaces point out the need for turning the drum to remove the matching ridges.

Visually check the drum for scoring. A scored brake drum will prevent a proper adjustment between brake shoe and drum and cause new linings to wear quickly. Any defects found will require the drum to be machined. Drums are machined by the machine shop in the NMCB and at some shore installations. If the shop you are working in has a brake drum lathe, make sure that you know how to operate the lathe before attempting to machine a drum. Using the wrong procedures may ruin the drum and cause the vehicle or item of equipment to be deadlined. Before machining, check the specifications provided in the maintenance manual. These specifications tell you the maximum amount of metal that can be removed from the drum and allow it to provide adequate braking. Many late model brake drums are stamped by the manufacturer to indicate the maximum inside dimension permissible for the brake drum.

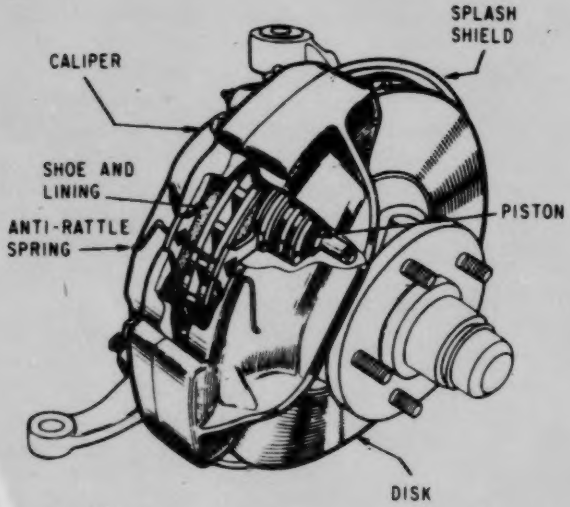
For maximum braking efficiency, the arc of the shoes must match the drums. This means that the shoes must be ground to match the curvature of the drum when it is machined. Most shops are equipped with a special machine to perform this task. If none is available, the shoes can be installed but the brakes will not become fully effective until the shoes wear enough to match the braking surface of the drum, and frequent adjustment will be needed until they do wear sufficiently.

DISK BRAKE ASSEMBLIES

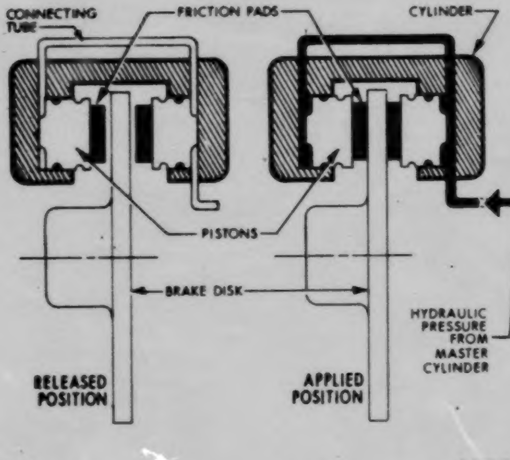
The disk brake assembly (fig. 10-19) consists of a metal disk and caliper assembly. The disk, which is bolted to the wheel hub, rotates with the wheel of the vehicle. The caliper assembly, which is attached to the steering knuckle, is stationary.

The disks are usually solid when used on lightweight vehicles and vented (for cooling) on heavy vehicles. Both sides of the disk are machined to provide a smooth friction surface. The caliper contains one or more hydraulic pistons which cause the brake shoes (one on either side of the disk) to squeeze the disk in a viselike manner.

Figure 10-20 illustrates the operation of a typical disk brake assembly. In actual application, the brake shoes (friction pads) are held in light contact with the disk when the brakes are released by a piston return spring.



115.225
Figure 10-19.—Disk brake assembly.



115.226
Figure 10-20.—Sectional view of disk brake in released and applied position.

Some disk brake shoes have telltale tabs which contact the disk when lining wear has reached a predetermined point. This results in a scraping noise when the vehicle is operated, warning the operator that the brake shoes are badly worn and should be replaced.

Disk brakes require no adjustment. However, you will occasionally have to add brake fluid to the master cylinder reservoir which supplies fluid for the disk portion of the braking system, because the piston return springs, by keeping the shoes against the disk as wear occurs, create a larger cavity for the fluid in the caliper assembly. A booster assembly is often used in disk brake systems as they have no self-energizing feature.

Some features of the disk brake make it more desirable then the drum brake; namely, braking action is instantaneous when pressure is applied to the caliper assembly, fading caused by the heat is eliminated, and the brakes are not affected when water is splashed onto the disk and linings.

Disk Brakes Servicing

Anytime a vehicle having disk brakes is scheduled for maintenance, the disks should be inspected for scoring and hard spots. Slight scoring results form normal braking. A disk that is scored less than 0.015 inch can be used without machining if the overall thickness of the disk is still within the manufacturer's specifications. Heavy scoring or hard spots require the disk to be machined.

The rust ridges that build up as wear occurs are of no concern unless new shoes are to be installed. Placing new shoes on a disk that has rust ridges causes the shoes to seat on the ridge, resulting in poor braking. These ridges should be removed by grinding or machining prior to installing new shoes. Hard spots are removed by grinding the same as if found on the conventional drum. A special lathe is used for maching disks. If none is available, the metal lathe in the machine shop and a grinding attachment will do the job.

A test should be made when shoes are replaced to determine if the disk has excessive runout or thickness variation. Either condition will cause erratic braking similar to that caused by a warped drum on conventional brakes.

Runout or wobble of the disk as it rotates must be checked with the use of a dial indicator, while thickness variation is determined by measuring the thickness of the disk in at least three places approximately 1 inch from the outer edge of the disk. Should either of these tests indicate a faulty disk, the disk must be machined. If it is worn excessively, it must be replaced.

Disk Brake Lining Replacement

Disk brakes have flat linings bonded to a metal plate or shoe. The shoe is not rigidly mounted inside the caliper assembly, thus it is said to float. The shoes are held in position by retainers or internal depressions (pockets machined into the caliper).

To remove the shoes, raise the front of the vehicle and remove the wheels. Next, remove approximately two-thirds of the fluid from the master cylinder and discard. Do not remove all of the fluid or bleeding of the system will be required on reassembly. The shoes can now be removed following the manufacturer's procedures. These vary depending on the manufacturer and the model. Some models allow removal of the shoes with the caliper mounted on the vehicle, while other designs require removal of the caliper before the shoes can be extracted. In either case, the pistons should be bottomed in the bores of the caliper assembly to release any tension on the shoes. This allows clearance for any rust buildup (ridge) at the outer edge of the disk.

Note: The rust buildup near the edge of the disk may have to be removed in order for the new shoes to seat properly on the disk.

The next step is to remove the old shoes and insert the new shoes. Now, remount the caliper or replace the shoe retainers torquing all bolts according to the manufacturer's specifications. Refill the master cylinder and apply the brakes a few times. Then, check for any leaks at the pistons in the caliper. If none are present, replace the wheels and lower the vehicle. A road test should be made to insure that the brakes are working properly and also to seat the new shoes on the disks. Several (3 or 4) heavy brake applications at approximately 35 to 40 miles per hour will work. If the brakes function normally after the braking test, the job is complete.

Servicing Caliper Assemblies

Servicing disk brake caliper assemblies usually involves the replacement of pistons, seals, and dust boots. To perform this type of service, it will be necessary to remove the caliper assembly from the vehicle. Carefully follow the procedures given in the manufacturer's maintenance manual when removing, repairing, and resinstalling disk brake caliper assemblies.

SERVICING HYDRAULIC SYSTEMS

Servicing hydraulic brake systems includes maintaining the proper level of hydraulic fluid in the master cylinder reservoir, checking the system for leaks and worn parts, and bleeding the brakes.

If the brake pedal goes to the vehicle floor when pushed down, first check the brake fluid level in the master cylinder, check for leaks around the master cylinder, wheel cylinders, and brake lines.

When adding hydraulic fluid, be sure it is the type recommended by the manufacturer.

Dirt and dust that accumulate around the filler opening can work into the operating mechanism and prevent a valve from sealing properly. See that all dust and dirt are removed before you remove the filler plug. Add enough fluid so that the level reaches just below the filler cover or plug opening. After filling the reservoir, see that the vent is open and the filler cover or plug is tight.

Continual refilling of the fluid reservoir is a sure sign of leakage requiring repairs in the brake wheel cylinders, the master cylinder, or loose fitting or broken lines in the brake system. Fluid lost at these places can be detected easily. Before tightening the fitting or removing sections of tubing for repairs, wipe them dry and clean, then have an assistant apply the brake. In this way you can be sure that you have found all the leaks.

Leaks and loose joints not only allow fluid to escape from the system, but also permit air to enter it. Air in a hydraulic brake system should be suspected when the brake pedal feels soft and spongy. This air must be bled from the system to obtain a solid pedal.

The procedures outlined below are for bleeding the single hydraulic system. Should you be servicing a dual system (drum or disk) the procedures may vary. Always consult the manufacturer's manual before bleeding dual brake systems.

One method of bleeding hydraulic brake lines to remove air from the system is done at the wheel brake cylinders as shown in figure 10-21. You will do this job often in servicing brakes, especially after they have been relined, or if any part of the system has been disconnected. Each hydraulic brake cylinder has some kind of a bleeder screw device (or valve) extending from the brake backing plate.

To bleed the lines proceed as follows: Fill the reservoir with brake fluid to one-fourth inch from the top, and keep it full during the bleeding operation.

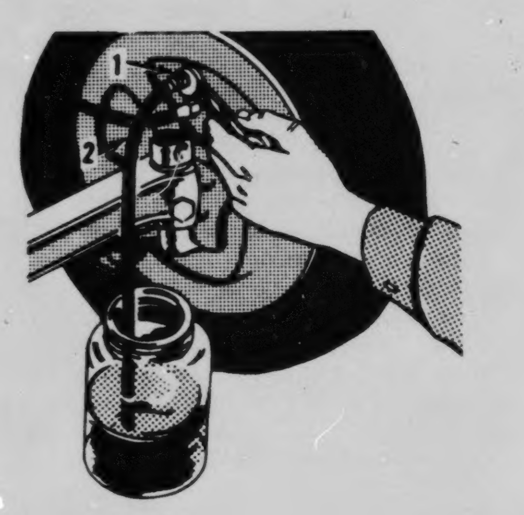


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Figure 10-21.—Bleeder brake lines, (1) Bleeder screw, (2) Bleeder hose.

Attach a short length of rubber hose to the bleeder screw and allow the loose end to be submerged in a clean glass container of brake fluid. Most bleeder screws have cap screws to protect the threaded opening to which you attach the bleeder hose.

Now, have an assistant push in the brake pedal to put pressure on the brake system, while you operate the bleeder screw, and watch for air bubbles in the glass container. Pushing down on the brake pedal slowly as far as it will go forces the fluid out of the bleeder valve through the hose into the glass container. With the fluid comes the air that is trapped in the line. It may be necessary to pump the brake pedal six or seven times before fluid without air can be seen entering the glass container. Check the reservoir after every third or fourth stroke of the brake pedal, so that the master cylinder will not be pumped dry, and the system will not fill with air.

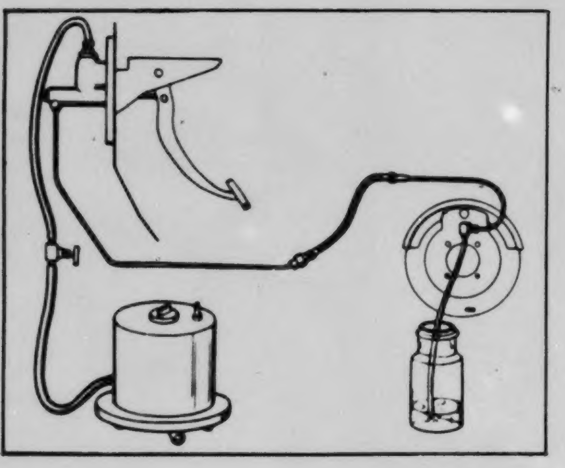
Bleed one wheel cylinder at a time. Do the one farthest away from the master cylinder first, so that all the air possible can be removed at the first bleeding operation.

When bubbles no longer escape from the bleeder hose, close the bleeder screw tightly, remove the bleeder hose, and reinstall the bleeder screw cap screw. Then proceed to the next wheel cylinder, and repeat the process until all the cylinders have been bled.

Pressure bleeding of a hydraulic system is preferred to the method just described, but requires equipment of the type shown in figure 10-22.

A pressure bleeder with fittings and adapter for connecting to the master cylinder fluid reservoir(s) is necessary to pressure bleed the system. Be sure there is enough brake fluid in the pressure bleeder tank to complete the bleeding operation and the tank is charged with adequate air pressure for the system you are servicing.

Fill the master cylinder reservoir(s) with clean brake fluid. Attach the pressure bleeder hose to the master cylinder reservoir(s), using the necessary fitting or adapter. Open the valve in the pressure bleeder hose to pressurize the brake hydraulic system.



81.496

Figure 10-22.—Pressure bleeding of brake system.

Attach a bleeder drain hose to the right rear wheel cylinder bleed screw, as shown in figure 10-21. Submerge the free end of the hose in a glass container partially filled with brake fluid.

Loosen the bleed screw. When fluid coming from the submerged end of the hose is free of air bubbles, close the bleed screw and remove the bleeder hose. Repeat at the left rear, right front, and left front wheel cylinders in that order.

If the hydraulic system being bled includes a dual system master cylinder with two filler caps, connect the pressure bleeder to the front reservoir to bleed rear wheels and to the rear reservoir to bleed front wheels.

NOTE: Some early dual system master cylinders with two filler caps have an opening between the two reservoirs. On these units, a sealed type filler cap should be installed in one opening and the pressure bleeder connected to the other. The bleeder may remain attached to the same opening while bleeding all four wheels.

When the bleeding operation is completed, close the valve in the pressure bleeder hose and disconnect the bleeder from the master cylinder. Be sure the master cylinder fluid level is within 1/4-inch of the top of the reservoir(s) and install filler cap(s) or a diaphragm and cover, if used.

VACUUM BOOSTERS

On many modern vehicles, vacuum boosters are utilized with the hydraulic brake system to provide easier brake application. In a hydraulic brake system there are limitations as to the size of the master and wheel cylinders which can be practically employed. Furthermore, the physical strength of the driver limits the amount of force which can be applied. This is especially true unless the brakes are self-energizing. These factors restrict the brake shoe to brake drum pressure obtainable. Vacuum boosters increase or boost this braking force.

There are various designs of vacuum boosters, but basically they all operate in the same manner.

In *Basic Machines* you learned that air has weight–about 15 pounds per square inch at sea level. This weight of the air or atmospheric pressure is used to operate vacuum boosters.

It is impossible to create a perfect vacuum, but by pumping air from a container it is possible to obtain a difference in pressure between the outside and inside of the container, or a partial vacuum. If the container were suddenly opened, outside air would rush into the container to equalize the pressure. It is upon this principle that the power cylinder of a vacuum booster system operates.

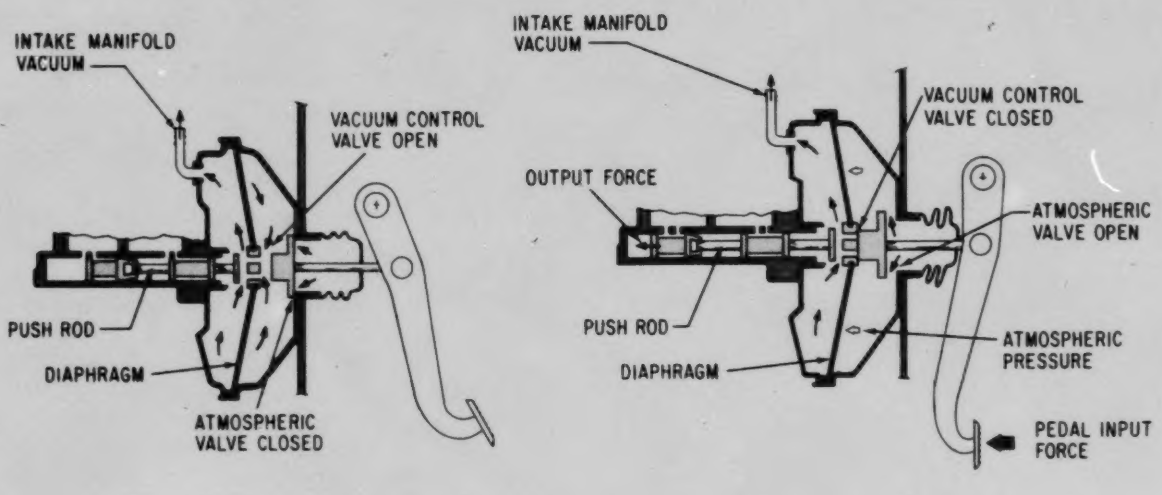
The power brake cylinder (fig. 10-23) is vacuum suspended. If the cylinder is air suspended, atmospheric pressure is present on both sides of the diaphragm. When the brakes are applied, atmospheric pressure is cut off on one side of the diaphragm and vacuum is applied to that same side. Atmospheric pressure then forces the diaphragm toward the side with the vacuum.

If the cylinder is vacuum suspended, vacuum is present on both sides of the diaphragm until the brake pedal is depressed. When the brakes are applied, vacuum is replaced on one side of the diaphragm by atmospheric pressure, causing the diaphragm to move toward the side which has the remaining vacuum.

The power brake unit involves the master cylinder and linkage only. Other parts of the brake system are like those in conventional brakes. Two external lines are generally connected to the power brake assembly: a vacuum connection to the intake manifold (vacuum reservoir on some installations) and one or more hydraulic connections leading into the hydraulic brake system.

On many installations a vacuum reservoir is inserted between the power unit and the intake manifold. The purpose of the reservoir is to make vacuum available for a short time to the booster unit should the vehicle have to quickly stop with a stalled engine. A check valve in the reservoir maintains a uniform vacuum within the system should engine vacuum drop off. This check valve prevents vacuum from bleeding back to the intake manifold when manifold vacuum is less than the vacuum in the tank.

All modern power brakes retain some pedal resistance, permitting the driver to maintain a certain amount of pedal feel. For example, a



RELEASED

APPLIED

81.564

Figure 10-23.—Modern automotive power brake assembly.

light pressure upon the pedal will give a light braking force while a heavy pressure upon the pedal will cause severe brake application. If the vacuum section of the power unit should fail, brake application can still be obtained by direct mechanical pressure on the master cylinder piston.

The vacuum-hydraulic booster unit used in most passenger cars and light trucks equipped with power brakes is the integral type, so-called because the power unit and master cylinder are combined in a single assembly. The most common integral types all use a single or tandem diaphragm and are of the vacuum suspended type. The power unit uses a master cylinder constructed in the same manner as the conventional dual master cylinder.

If brake trouble is encountered, check the brake system in the same manner as for conventional brakes. Air in the hydraulic lines will cause a spongy pedal. Oil or grease soaked brake linings will cause the brakes to grab. Power brakes require the same maintenance as other brakes.

To check the power booster unit for correct operation, stop the engine and apply the brakes several times to deplete the vacuum reserve in the system. Next, partly depress the pedal and while holding it in this position, start the engine. If the booster system is operating properly, the pedal will tend to fall away under foot pressure and will require less effort for you to hold it in the applied position. If no action is felt, the booster is not functioning.

If the power unit is not giving enough assistance, check the engine vacuum. If the engine vacuum is abnormally low (below 14 inches at idle), tune up the engine to raise the vacuum reading and try the brakes. A steady hiss when the brake pedal is depressed indicates a vacuum leak is preventing proper operation of the cylinder.

Vacuum failure, which results in a hard pedal, may be due to a faulty check valve, a collapsed vacuum hose to the intake manifold, or internal leaks in the power brake unit.

A tight pedal linkage (insufficient push rod clearance) will sometimes result in a hard pedal. If this connection is free and the brakes still fail to release properly, the power unit must be replaced.

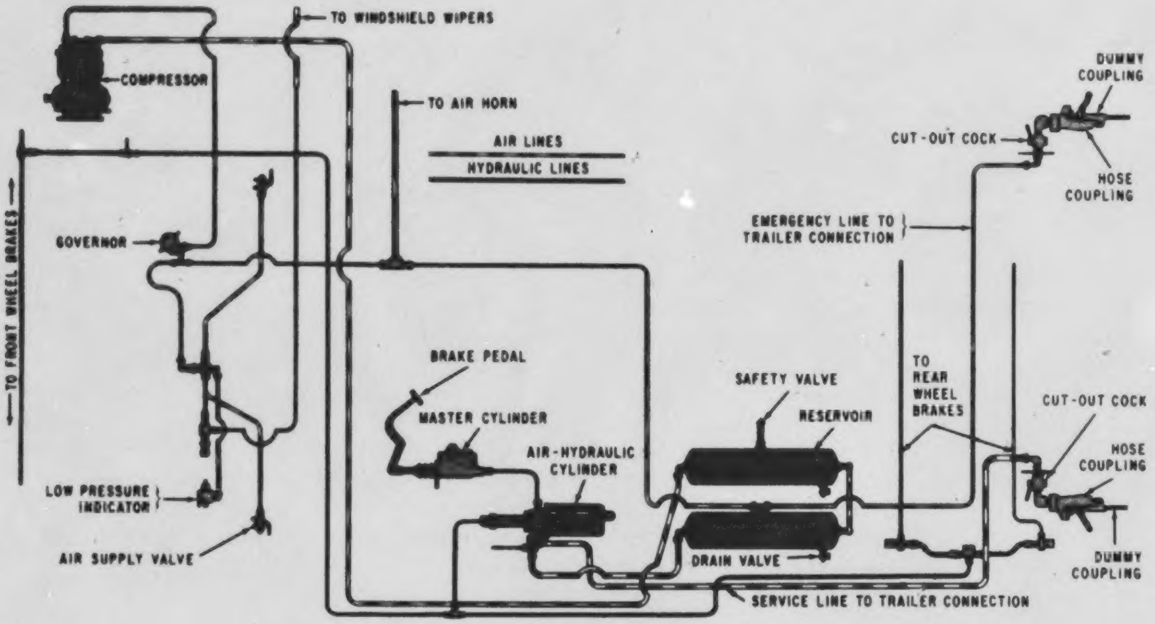
In addition to hydraulic system problems, the brakes may fail to release as a result of a blocked passage in the power piston, a sticking air valve, or a broken air valve spring.

Any malfunction occurring in the power unit will necessitate removing the power unit from the vehicle for repairs or replacement. Some power units may be rebuilt or repaired. Should you have any questions concerning repairs on the power braking system you are working on, consult your supervisor or the manufacturer's manual for the proper procedures to follow when testing or repairing this unit.

AIR-OVER-HYDRAULIC BRAKE SYSTEM

An air-over-hydraulic brake system is shown in figure 10-24. This system combines the use of compressed air and hydraulic pressure for brake operation. The essential difference between the straight hydraulic brake system and the air-over-hydraulic brake system lies in the air-hydraulic-power cylinder. The air-hydraulic-power cylinder (fig. 10-25) is a self-contained power brake unit which is made up of three basic assemblies: the compressed air cylinder, the slave cylinder, and the control valve.

The COMPRESSED AIR CYLINDER consists of a piston operating within a cylinder body. This piston actuates a push rod which is attached to the hydraulic piston of the slave cylinder. Movement of the piston in the compressed air cylinder is controlled by the amount of air, under pressure, allowed to enter through the control valve. The cylinder body is attached to the end plate on which the slave cylinder and control valve are mounted. A return spring forces the power piston to the

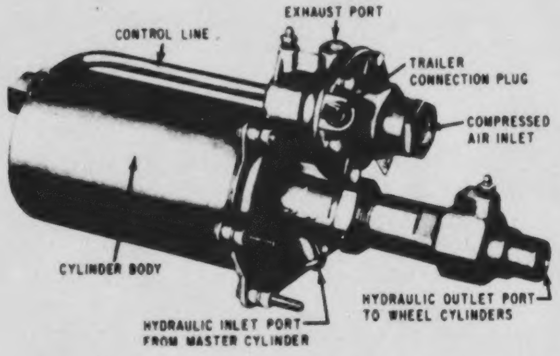

TO WINDSHIELD WIPERS
COMPRESSOR
TO AIR HORN
AIR LINES
HYDRAULIC LINES
DUMMY COUPLING
CUT-OUT COCK
HOSE COUPLING
EMERGENCY LINE TO TRAILER CONNECTION
TO FRONT WHEEL BRAKES
GOVERNOR
BRAKE PEDAL
MASTER CYLINDER
SAFETY VALVE
RESERVOIR
TO REAR WHEEL BRAKES
CUT-OUT COCK
HOSE COUPLING
AIR-HYDRAULIC CYLINDER
LOW PRESSURE INDICATOR
AIR SUPPLY VALVE
DRAIN VALVE
DUMMY COUPLING
SERVICE LINE TO TRAILER CONNECTION

81.292

Figure 10-24.—Diagram of an air-hydraulic brake system.

released position when the brake pedal is released.

The SLAVE CYLINDER consists of a cylindrical housing in which the hydraulic piston operates. The outlet cap houses a residual line check valve and a ball check valve is located in the hydraulic piston.


EXHAUST PORT
CONTROL LINE
TRAILER CONNECTION PLUG
COMPRESSED AIR INLET
CYLINDER BODY
HYDRAULIC OUTLET PORT TO WHEEL CYLINDERS
HYDRAULIC INLET PORT FROM MASTER CYLINDER

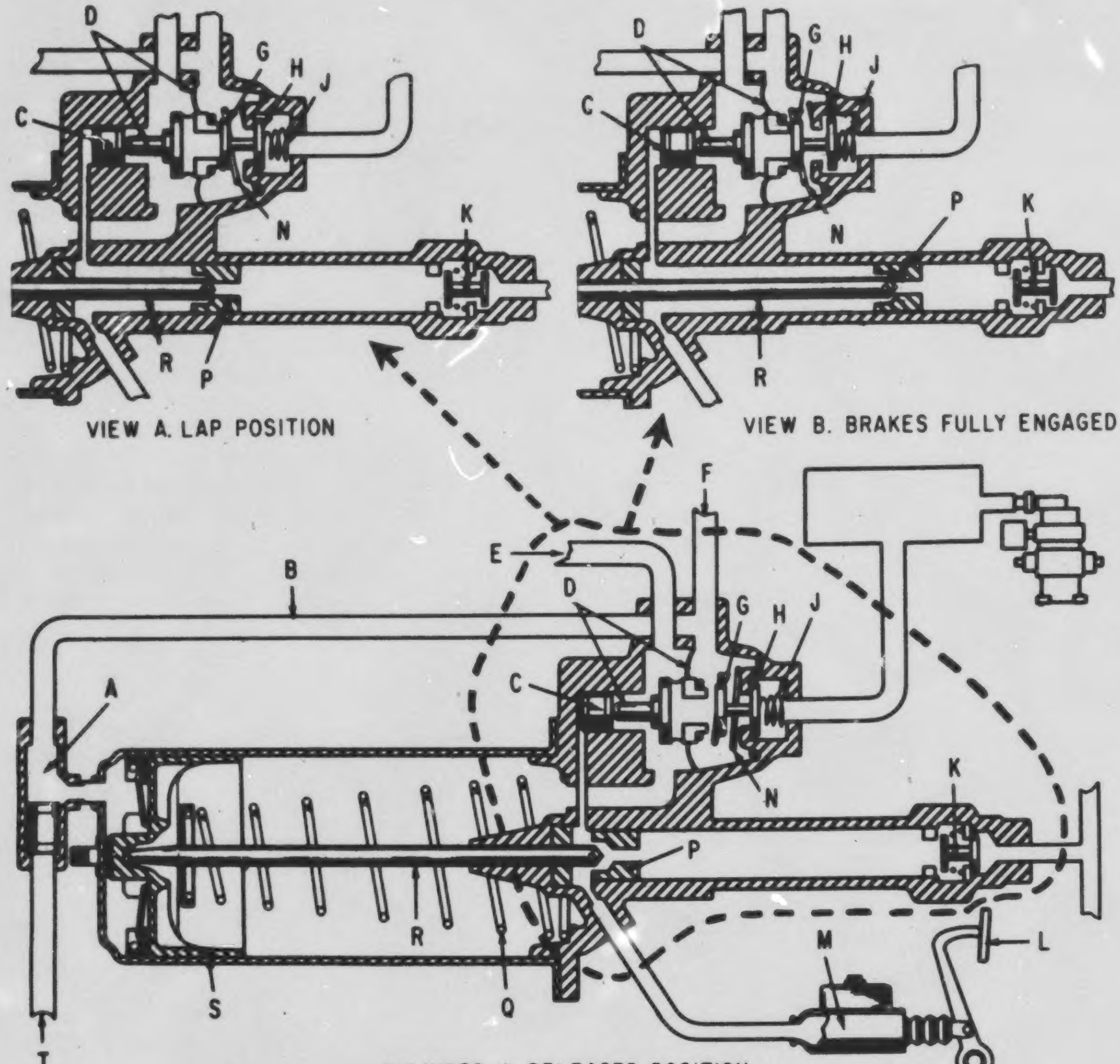
81.491

Figure 10-25.—Air-hydraulic (Air-Pak) power cylinder assembly.

The CONTROL VALVE consists of two poppets operating within a housing and actuated by a hydraulic relay piston and reactionary-type diaphragm. An air control line connects the control valve to the compressed air cylinder.

Figure 10-26 illustrates the air-hydraulic power cylinder in the released position. Views A and B illustrate the position of the valves and slave cylinder hydraulic piston during light and heavy brake pedal application.

When the brakes are partially applied (fig. 10-26, view A), pressure is transmitted by the brake fluid to the hydraulic piston in the slave cylinder and the relay piston. As hydraulic pressure builds, the relay piston moves the diaphragm forward, closing the atmospheric poppet and slightly opening the air pressure poppet. Air under pressure then passes through the air control line and forces the power piston


D
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VIEW A. LAP POSITION
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G
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R
VIEW B. BRAKES FULLY ENGAGED
F
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D
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A
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K
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R
M
L
S
Q
T
CYLINDER IN RELEASED POSITION

A. Double check valve assembly
B. Air control line
C. Relay piston
D. Diaphragm assembly
E. Exhaust port
F. Atmospheric inlet
G. Atmospheric poppet
H. Air Pressure poppet
J. Poppet return spring
K. Residual line check valve assembly
L. Brake pedal
M. Master cylinder
N. Diaphragm return spring
P. Hydraulic piston
Q. Piston return spring
R. Push rod
S. Power piston
T. Trailer connection

81.494:493:495

Figure 10-26.—Air hydraulic (Air-Pak) power cylinder during operation.

forward until the air pressure on the diaphragm, in combination with spring pressure, allows the air pressure poppet to close. The degree of brake application is determined by the amount of compressed air trapped in the power cylinder body when brake pedal movement stopped. Unless more pressure is applied or the brake pedal is released, the brakes will remain in the partially applied position.

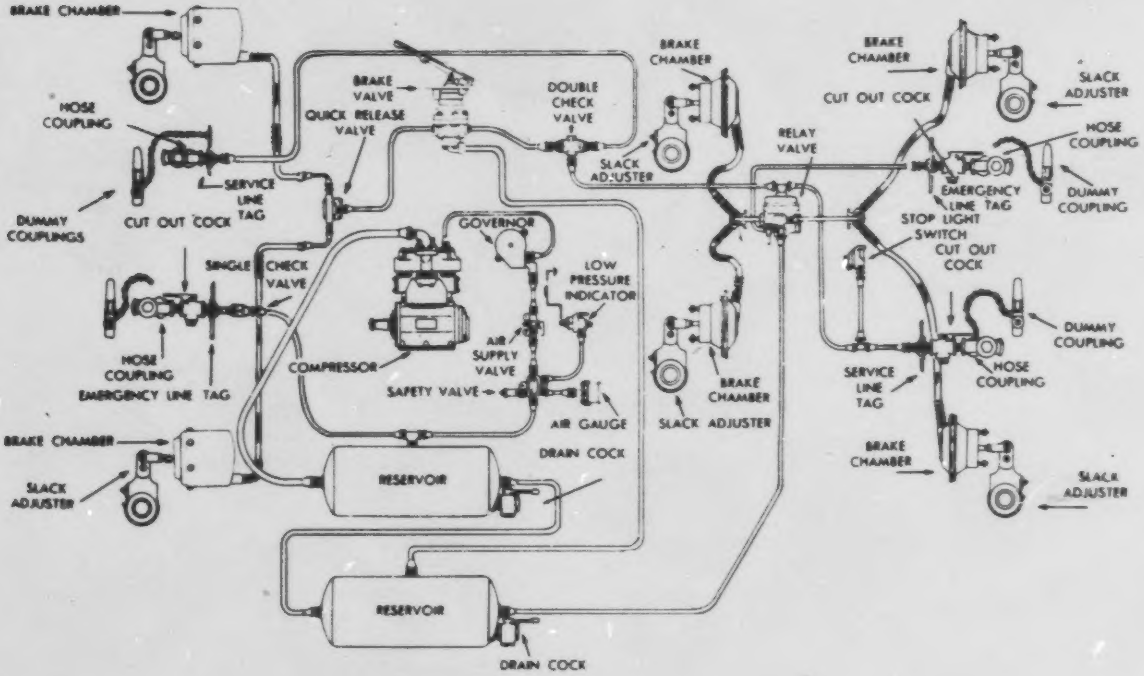
View B of figure 10-26 illustrates the effect of applying high brake pedal pressure. Under this condition, the air pressure poppet will be held open, allowing a full volume of air under pressure to enter the compressed air cylinder and cause full brake application.

The residual line check valve maintains a small amount of pressure in the hydraulic system when the brakes are released. This pressure prevents leakage at the wheel cylinders just as in a conventional hydraulic brake system.

AIR BRAKE SYSTEMS

Air, like all gases, is easily compressed. Compressed air exerts pressure and this pressure will be equal in all directions. Air under pressure can be conveniently stored and carried through lines or tubes. Considerable force is available for braking since operating air pressure may be as high as 100 psi. All brakes on a vehicle, and on a trailer, when one is used, are operated together by means of a brake valve. This valve and relative location of most of the basic assemblies of an air brake system are shown in figure 10-27 and discussed in the following paragraphs.

The COMPRESSOR is driven from the engine crankshaft or one of the auxiliary shafts. The three common methods of driving the compressor from the engine are gear, belt, and chain. There are two types of compressors in general use in the Navy: the reciprocal (piston) type and the rotary vane type. The compressor


BRAKE CHAMBER
HOSE COUPLING
DUMMY COUPLINGS
CUT OUT COCK
SERVICE LINE TAG
BRAKE VALVE
QUICK RELEASE VALVE
DOUBLE CHECK VALVE
SLACK ADJUSTER
SINGLE CHECK VALVE
HOSE COUPLING
EMERGENCY LINE TAG
GOVERNOR
LOW PRESSURE INDICATOR
AIR SUPPLY VALVE
COMPRESSOR
SAFETY VALVE
AIR GAUGE
BRAKE CHAMBER
SLACK ADJUSTER
DRAIN COCK
RESERVOIR
RESERVOIR
DRAIN COCK
BRAKE CHAMBER
SLACK ADJUSTER
RELAY VALVE
BRAKE CHAMBER
SLACK ADJUSTER
BRAKE CHAMBER
CUT OUT COCK
SLACK ADJUSTER
HOSE COUPLING
EMERGENCY LINE TAG
DUMMY COUPLING
STOP LIGHT SWITCH
CUT OUT COCK
DUMMY COUPLING
SERVICE LINE TAG
HOSE COUPLING
BRAKE CHAMBER
SLACK ADJUSTER

81.284

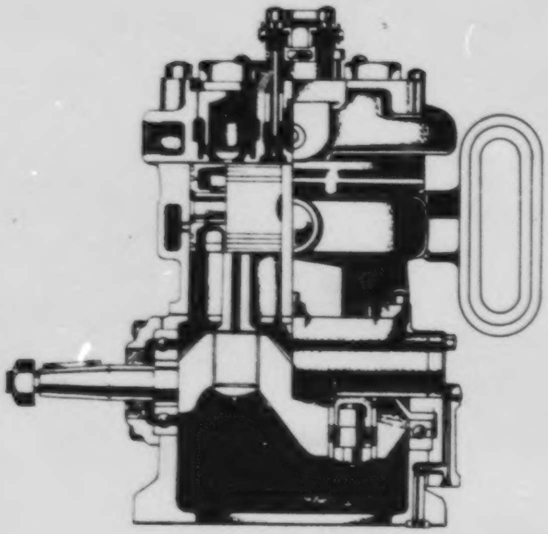
Figure 10-27.—Typical air brake system.

may be lubricated from the engine crankcase or be self-lubricated. Cooling may be either by air or liquid from the engine.

The reciprocal air compressor (fig. 10-28) operates continuously while the engine is running, but the actual compression is controlled by the governor. Air is drawn through the air strainer and intake ports into the cylinder by the partial vacuum created on the piston downstroke. These ports are covered as the piston starts its up-stroke and air in the cylinder is compressed. This pressure lifts the discharge valve and the compressed air is discharged to the reservoirs. The discharge valve closes as soon as upward travel of the piston stops.

The purpose of the compressor GOVERNOR is to automatically maintain the air pressure in the reservoir between the maximum pressure desired (100-105 psi) and the minimum pressure required for safe operation (80-85 psi) by starting and stopping compression.

In the type 0-1 governor, (fig. 10-29) air pressure from the reservoir enters the governor through the strainer and is always present below the lower valve and in the spring tube. As the air pressure increases, the tube tends to straighten out, and decrease pressure on the valve.



81.459

Figure 10-28.–Reciprocal air compressor.

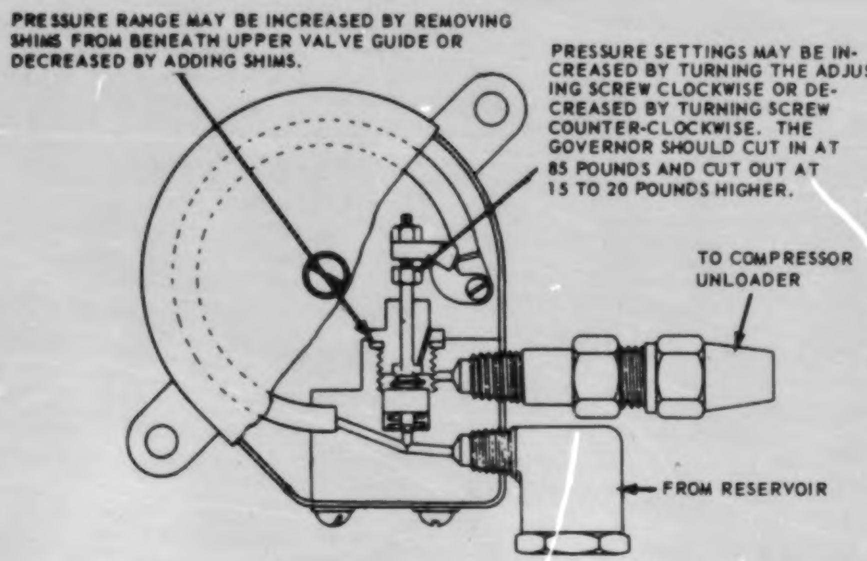
When the reservoir air pressure reaches the cutout setting of the governor (100-105 psi), the spring load of the tube on the lower valve has been reduced enough to permit air pressure to raise the lower valve off its seat. This movement of the lower valve raises the upper valve to its seat which closes the exhaust port. Air then flows up through the small hole in the lower valve and out the upper connection to the unloader assembly located in the compressor cylinder head. When the unloader valves open, the compression of air is stopped.

When reservoir pressure is reduced to the cut-in setting of the compressor governor (80-85 psi), the governor tube again exerts sufficient spring pressure on the valve mechanism to depress and close the lower valve and open the upper valve, thereby shutting off and exhausting the air from the compressor unloading mechanism and compression is resumed.

Pressure range and setting should be checked periodically using an air gage known to be accurate. Pressure range may be changed in the type 0-1 governor by adding shims beneath the upper valve guide to decrease the range, or removing shims to increase the range. Pressure settings may be changed, if necessary, by turning the adjusting screw to the left to increase the setting or to the right to decrease the setting.

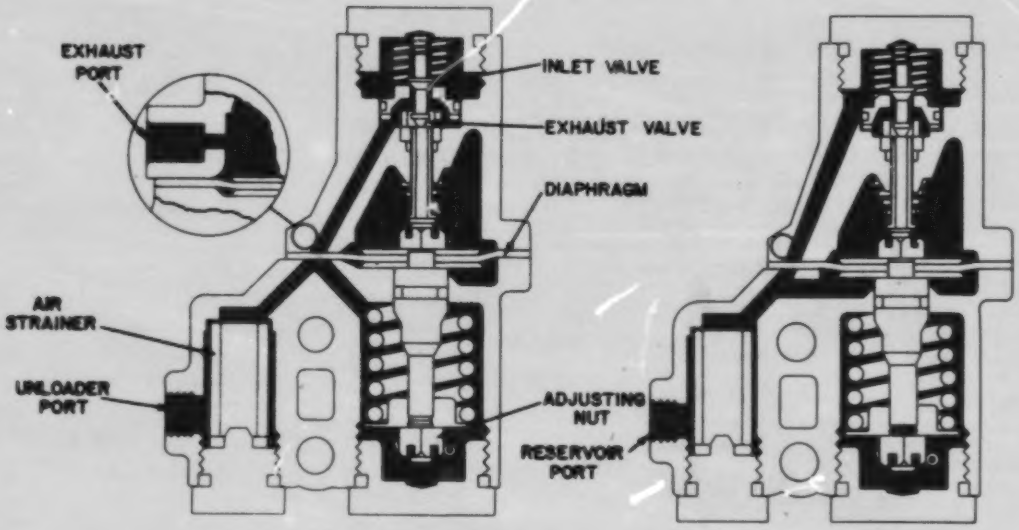
The strainer should be removed periodically and cleaned. Check the governor periodically for excessive leakage in both the cut-in and cut-out positions. If the governor fails to operate properly, it should be repaired or replaced.

When the reservoir pressure reaches the cut-out setting (100-105 psi) in the type D governor (fig. 10-30), the governor diaphragm is subjected to sufficient air pressure to overcome the spring loading, allowing the valve mechanism to move up, permitting the exhaust stem to close the exhaust valve and to open the inlet valve. Reservoir pressure then passes through the


PRESSURE RANGE MAY BE INCREASED BY REMOVING SHIMS FROM BENEATH UPPER VALVE GUIDE OR DECREASED BY ADDING SHIMS.
PRESSURE SETTINGS MAY BE INCREASED BY TURNING THE ADJUSTING SCREW CLOCKWISE OR DECREASED BY TURNING SCREW COUNTER-CLOCKWISE. THE GOVERNOR SHOULD CUT IN AT 85 POUNDS AND CUT OUT AT 15 TO 20 POUNDS HIGHER.
TO COMPRESSOR UNLOADER
FROM RESERVOIR

81.286

Figure 10-29.—Type 0-1 governor.


EXHAUST PORT
INLET VALVE
EXHAUST VALVE
DIAPHRAGM
AIR STRAINER
UNLOADER PORT
ADJUSTING NUT
RESERVOIR PORT

81.461

Figure 10-30.—Type D governor.

governor to operate the compressor unloading mechanism, stopping further compression of air by the compressor.

When the reservoir pressure is reduced to the cut-in setting (80-85 psi), the springloading within the governor overcomes the air pressure under the diaphragm. The valve mechanism is actuated, closing the inlet valve and opening the exhaust valve, thereby shutting off and exhausting the air from the compressor unloading mechanism and compression is resumed.

Pressure range and setting should be checked periodically, using an accurate air gage. The pressure range (pressure differential) between loading and unloading of the type D governor is a function of the design of the unit and should not be changed. The designed range for this governor is approximately 20 percent of the cut-out pressure setting. The pressure settings of the type D governor may be adjusted by turning the adjusting nut clockwise to increase or counterclockwise to decrease the settings.

Both strainers should be removed periodically and cleaned or replaced. The governor should periodically be checked for leakage at the exhaust port in both the cut-in and cut-out positions. If the governor fails to operate properly, it should be repaired or replaced.

The UNLOADER ASSEMBLY (fig. 10-31) is controlled by the governor. Air pressure from the governor opens the unloader valves to unload or stop compression in the compressor.

The unloader valve mounted in the compressor head may be either a poppet-type or a spring-loaded control valve.

The two steel tanks (fig. 10-27) which are components of most air brake systems, are called RESERVOIRS. These tanks are used to cool, store, and remove moisture from the air and give a smooth flow of air to the brake system.

A SAFETY VALVE consists of an adjustable spring-loaded ball check valve in a body. It is used to protect the system against excessive pressures and is usually mounted on a reservoir. The safety valve is set at 150 psi.

A PRESSURE GAGE mounted in the vehicle dash is connected to a line which contains reservoir pressure.

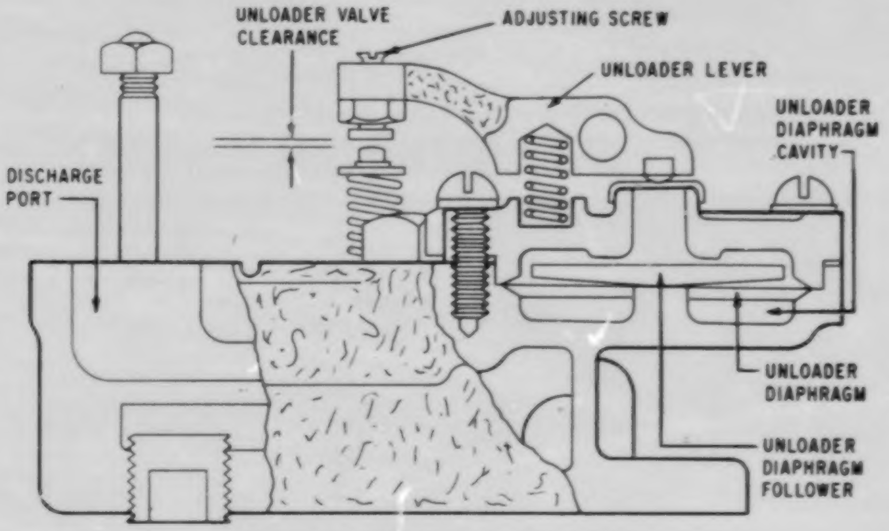
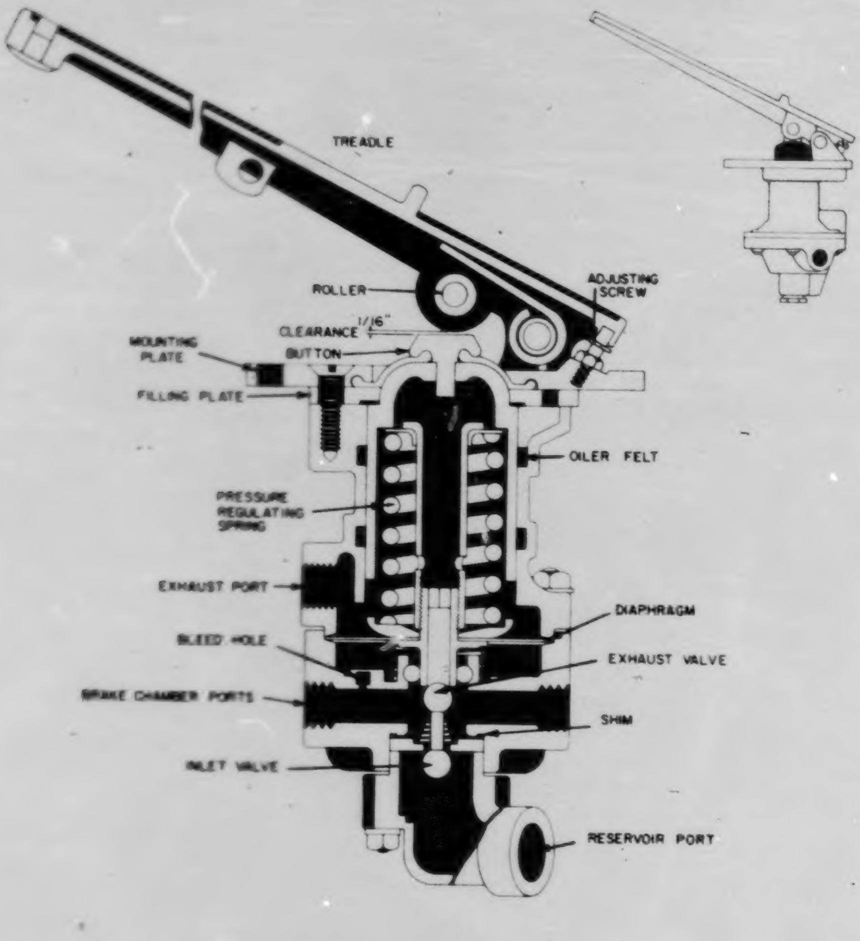


Figure 10-31.—Unloader assembly.

The **BRAKE VALVE** is the operator's control of the air brake system. When the brake valve is engaged, air from the reservoir flows through the valve to the brakes. The two brake valves commonly used in an air brake system are the treadle and hand type.

The **TREADLE** type brake valve (fig. 10-32) controls the air pressure delivered to the brake chambers. When the treadle is depressed, force is transmitted to the pressure regulating spring and diaphragm which is moved downward, contacting the exhaust valve and closing it. Continued movement opens the inlet valve and air pressure from the reservoir flows through the valve into the delivery lines to apply the brakes. As the air pressure increases below the diaphragm it overcomes the force above the diaphragm and the diaphragm raises slightly. This allows the inlet valve to close, but keeps the exhaust valve closed also, thus obtaining a balanced position. Further depression of the treadle increases the forces above the diaphragm and correspondingly increases the delivered air pressure until a new balanced position is reached.

Maintenance of the treadle type valve consists of periodic lubrication of the hinge and


TREADLE
ROLLER
ADJUSTING SCREW
1/16"
CLEARANCE
BUTTON
MOUNTING PLATE
FILLING PLATE
OILER FELT
PRESSURE REGULATING SPRING
EXHAUST PORT
DIAPHRAGM
BLEED HOLE
EXHAUST VALVE
BRAKE CHAMBER PORTS
SHIM
INLET VALVE
RESERVOIR PORT

81.463

Figure 10-32.—Treadle type brake valve.

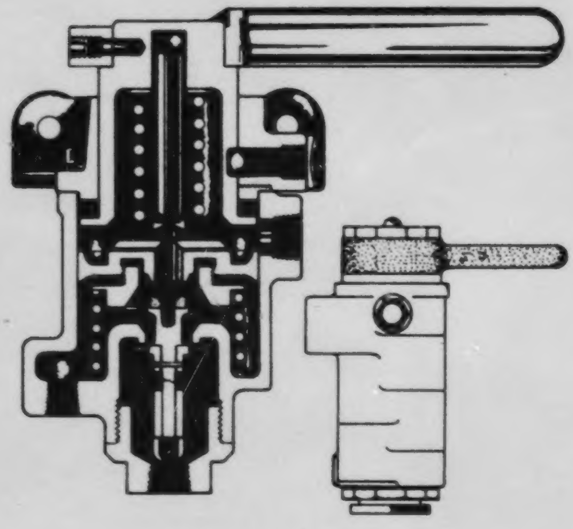
roller. Should the valve malfunction, it can be disassembled and cleaned. If cleaning does not cause proper operation of the valve, it must be replaced. The internal parts should be lubricated with vaseline after cleaning. This prevents moisture in the air system from causing corrosion and freezing of the valve.

The independent trailer control valve (fig. 10-33) provides the operator with control of his trailing load at all times. This valve functions in the same manner that the brake valve does except that the handle is turned, rather than depressed, to operate the valve. Maintenance procedures for this valve are the same as those given for the brake valve.

The BRAKE CHAMBER (fig. 10-34) or ROTO-CHAMBER (fig. 10-35) provides the mechanical force that applies the brakes. When the operator actuates the brake pedal, air under pressure enters the chamber behind the diaphragm, causing it to extend the push rod and apply the brakes.

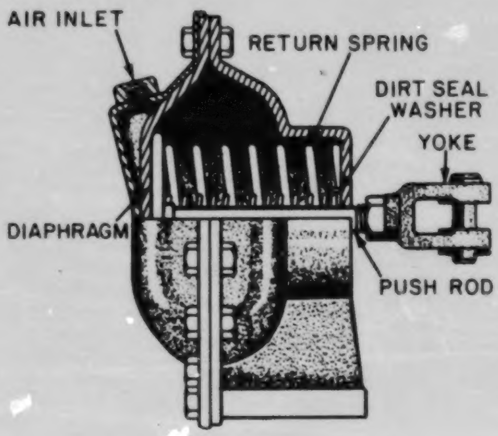
When the brake pedal is released, air is forced from the chamber by the brake shoe return springs acting on the linkage. After the shoes reach the fully released position, the return spring acting on the diaphragm causes it to return to its original position in the chamber.

Check alinement to avoid binding action. Check push rod travel periodically and when



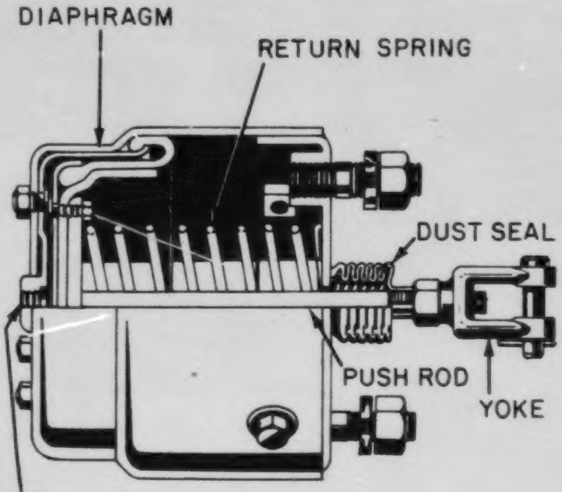
81.464

Figure 10-33.—Hand-type brake valve.



81.565

Figure 10-34.—Brake chamber.



81.466

Figure 10-35.—Brake roto-chamber.

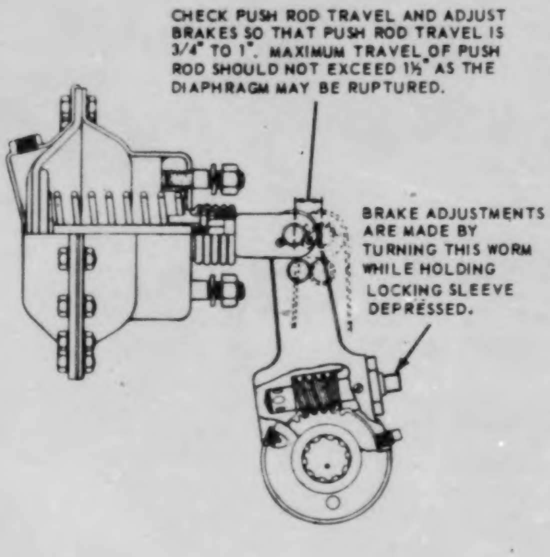
necessary, adjust brakes so that push rod travel is as short as possible without brakes dragging. The push rod length should be adjusted so that the angle between the center line of the slack adjuster and the brake chamber push rod is 90 degrees when the push rod is extended to the center of its working stroke.

Replace the diaphragm if worn or leaking. Replace the boot if it is worn or cracked. With the brakes applied, cover edges of diaphragm and bolt with soap suds to detect leakage. If leaks are present, tighten bolts uniformly until leakage is eliminated. Bolts should not be tightened so that the diaphragm shows signs of bulging or distortion. The maintenance of the brake chamber and roto-chamber is similar.

SLACK ADJUSTERS (fig. 10-36) provide a quick and easy method of adjusting brakes to compensate for lining wear. Air pressure admitted to the brake chamber or rotor-chamber when the treadle is depressed moves the slack adjuster toward the position indicated by the dotted lines.

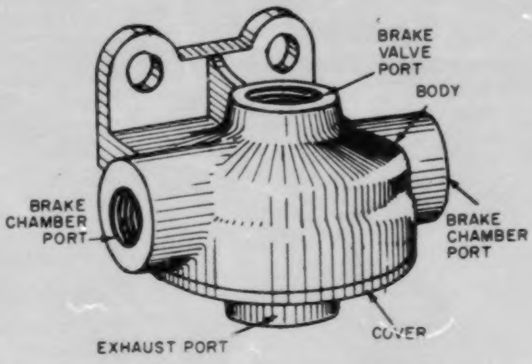
The entire slack adjuster rotates as a lever with the brake camshaft as the brakes are applied or released. The brake adjustments necessary to maintain proper slack adjuster arm travel (shoe and drum clearance) are made by turning the adjusting screw. This rotates the worm gear, camshaft, and cam, expanding the brake shoes so that the slack caused by brake lining wear is eliminated and the slack adjuster arm travel is returned to the correct setting. The slack adjuster rotates the brake camshaft and the attached cam (see fig. 10-1). The movement of the cam forces the brake shoes against the brake drum. Friction of the brake lining on the drum stops the turning movement of the wheel. When brakes are released, the brake shoe return spring pulls brake shoes back to disengaged position.

The QUICK RELEASE VALVE (fig. 10-37) exhausts brake chamber air pressure and speeds up brake release by reducing the distance the air would have to travel back to the brake valve exhaust port. When brakes are engaged, air from the brake valve enters into the quick release valve, forcing the diaphragm down. The center section of the flexible diaphragm closes off the exhaust port. Air pressure rushes through the quick release valve outlet ports to the wheel brake chambers. When the brakes are released, the air pressure above the quick release diaphragm is exhausted at the brake valve. As air pressure above the diaphragm is released, the air pressure below the diaphragm raises the center off the exhaust port, allowing the air in the


CHECK PUSH ROD TRAVEL AND ADJUST BRAKES SO THAT PUSH ROD TRAVEL IS 3/4" TO 1". MAXIMUM TRAVEL OF PUSH ROD SHOULD NOT EXCEED 1½" AS THE DIAPHRAGM MAY BE RUPTURED.
BRAKE ADJUSTMENTS ARE MADE BY TURNING THIS WORM WHILE HOLDING LOCKING SLEEVE DEPRESSED.

81.468

Figure 10-36.—Slack adjuster.


BRAKE VALVE PORT
BODY
BRAKE CHAMBER PORT
BRAKE CHAMBER PORT
EXHAUST PORT
COVER

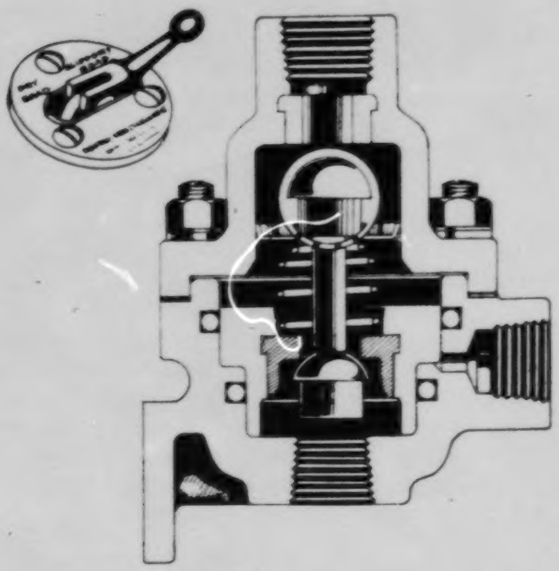
81.471

Figure 10-37.—Quick-release valve.

brake chambers to exhaust at the quick release valve. The leakage test is made with brakes applied by coating exhaust port with soap suds. Leakage is caused by dirt, worn diaphragm or seat. Correct by cleaning and replacing parts or by replacing the unit.

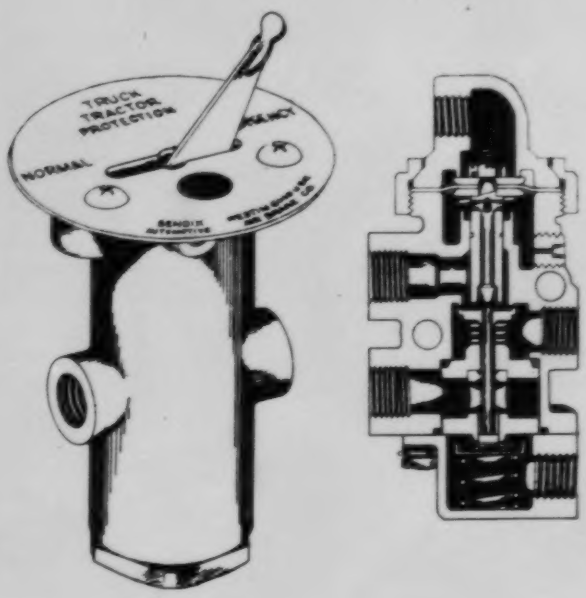
The COMBINED-LIMITING and QUICK-RELEASE VALVE (fig. 10-38) is used only in combination with a two-way valve in the air brake system of trucks and tractors. The combined-limiting and quick-release valve is interchangeable in mounting with the quick-release valve and serves the same purpose with the additional function of providing an automatic reduction of front wheel brake pressure, at the option of the driver, on slippery roads.

The primary purpose of the TRACTOR PROTECTION VALVE (fig. 10-39) is to protect the tractor air brake system under trailer breakaway conditions and under conditions where severe leakage develops in the tractor or trailer.



81.472

Figure 10-38.–Combined-limiting and quick-release valve.

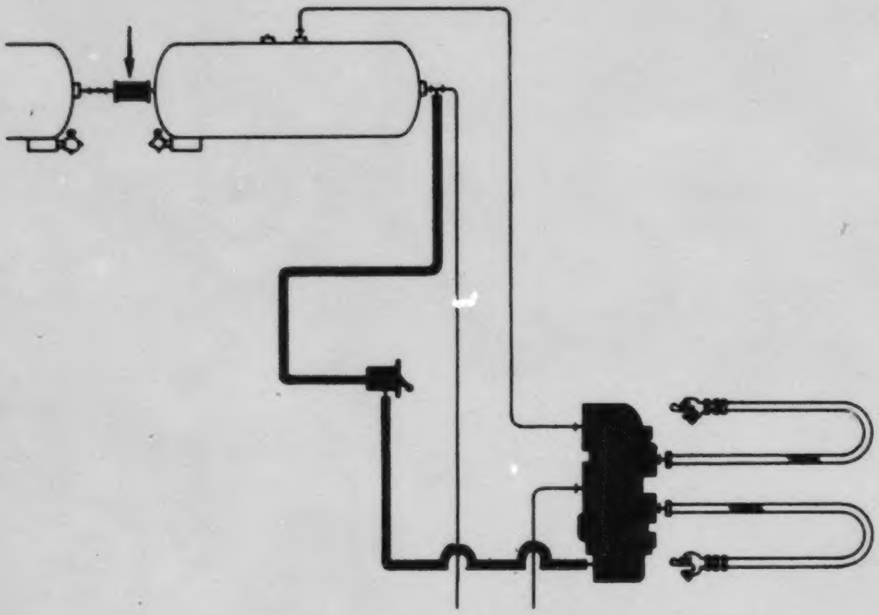


81.473

Figure 10-39.–Tractor protection valve and switch.

The tractor protection system functions as a set of remotely controlled cut-out cocks. (See fig. 10-40.) The trailer service and emergency lines pass through the valve. When the control valve is in the "normal" position, service and emergency braking functions of both tractor and trailer are normal. When the valve lever is in the "emergency" position, the trailer air brake lines are closed off on the tractor valve.

Should a condition resulting in severe air loss from the tractor or trailer air brake system be detected, or if for any other reason it is desirable to cause an emergency application of the trailer brakes, the driver can move the control valve lever to the "emergency" position. At this time both the trailer service and emergency brake lines will be closed off at the tractor protection valve. Such operation offers a convenient daily check of the relay emergency valve on the trailer where tractors and trailers are not disconnected over long periods of time. The driver should move the control to the "emergency" position when disconnecting a trailer or when operating a



81.474

Figure 10-40.—Tractor protection valve piping.

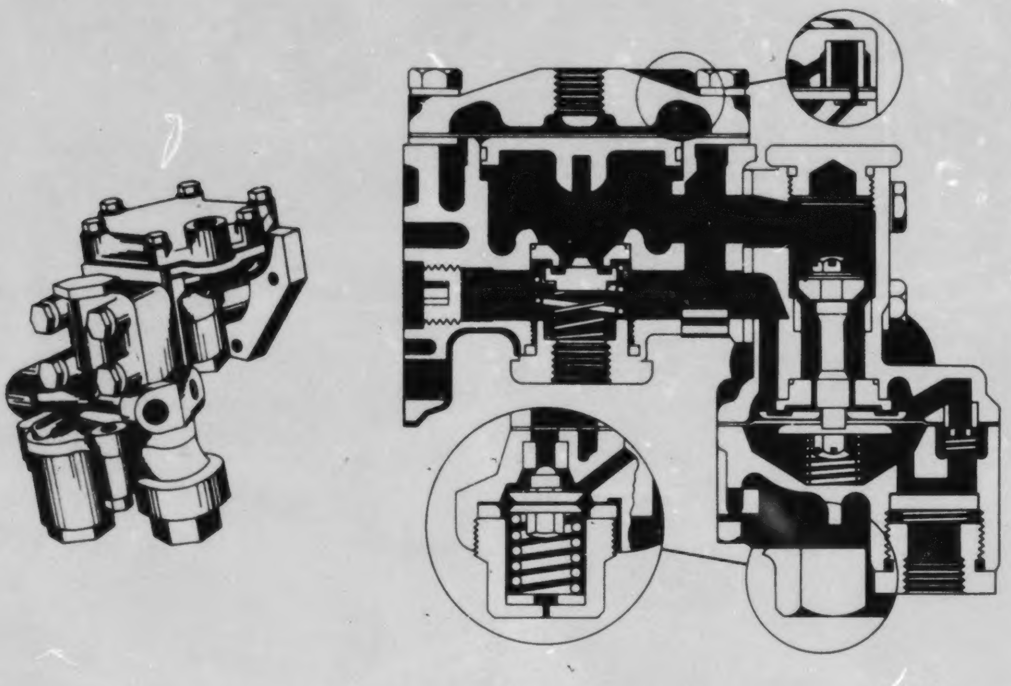
tractor without trailer if cut-out cocks are not installed in the trailer connections on the tractor. The tractor protection valve should not be used as a parking brake. It is not designed for that purpose.

The RELAY EMERGENCY VALVE (fig. 10-41) acts as a relay station to speed up the application and release of trailer brakes. It automatically applies the trailer brakes when the emergency line of the trailer is broken, disconnected or otherwise vented to atmosphere if the trailer air brake system is charged. It is used on trailers which require an emergency brake application upon breakaway from the truck or tractor.

When a tractor is connected to a trailer and the service and emergency lines are opened, the relay emergency valve permits charging the trailer air brake reservoir to approximately the same air pressure that is present in the tractor reservoirs. During normal operation of a tractor-trailer unit, the relay emergency valve functions as a relay valve and synchronizes trailer service brake air pressure and tractor service brake air pressure as the service foot brake valve on the tractor is operated. The trailer brakes can also be applied independently of the tractor brakes by use of the hand control brake valve on the tractor and the relay emergency valve on the trailer.

If a trailer is disconnected from a tractor for loading or unloading, or if the trailer is separated from the tractor under emergency breakaway conditions, or if its emergency line is vented to atmosphere by other means, the relay emergency valve applies the trailer brakes automatically at existing trailer reservoir pressure. If a trailer is to remain parked under these conditions, the wheels should be blocked to avoid the possibility of a runaway.

If it is desired to release the emergency brake application on the trailer under these conditions, the trailer reservoir drain cock can be opened, or the trailer air brake system can be recharged through the trailer emergency line.



81.476

Figure 10-41.—Relay emergency valve.

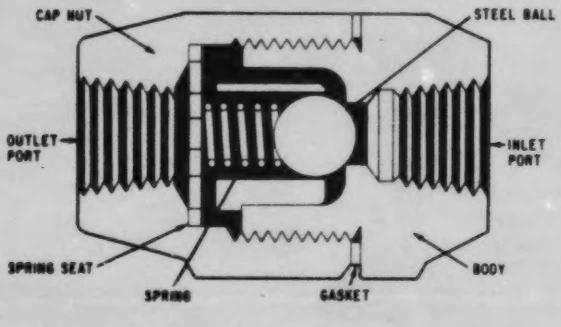
Check the relay emergency valve by moving the tractor protection control lever to the "emergency" position if tractor protection equipment is installed. If not, the valve can be checked by closing the emergency line cut-out cock and uncoupling the emergency line. Either way the trailer brakes should apply automatically. Trailer brakes should release, in the first case, when the control valve lever is moved to the "normal" position, and secondly when the emergency line is coupled or the cut-out opened.

The relay emergency valve is checked for leakage by application of soap suds with the brakes in the released, applied and emergency application position. Check the emergency air line coupling with soap suds to determine leakage with the valve in emergency application position. Leakage may be caused by dirt or worn parts which may be corrected by cleaning and/or replacing the unit.

CHECK VALVES ARE LOCATED in the lines of air brake systems to prevent the loss of air should a line rupture while in operation. These are placed at the entrances of the main air tanks and prevent the loss of air should the inlet line from the compressor fail. The ball-type check valve shown in figure 10-42 is typical of the type used on the semitrailer braking systems. Check valves may be either disk or ball and single or double units. Regardless of design, their function is the same.

AIR HOSES and AIR HOSE FITTINGS (fig. 10-43) provide a means of making a flexible air connection between points on a vehicle which normally change their position in relation to each other or between two vehicles. All the air hose assemblies used to connect the air brake systems from one vehicle to another are equipped with detachable fittings and spring guards.

When installing a hose assembly where both ends are permanently connected, use the air



81.478
Figure 10-42.—Ball-type single check valve.

hose connector assembly at either end as the union to permit tightening the hose connectors in place. Loosen the nut on one of the connector assemblies and then turn the hose in the loose connector to avoid kinking the hose.

DUMMY COUPLINGS (fig. 10-44) are used to prevent dirt and moisture from entering unused air lines. Bracket-type dummy couplings are mounted to the machine for storage of unused hose. Chain dummy couplings are attached to the machine by a chain and placed in couplings mounted on the machines.

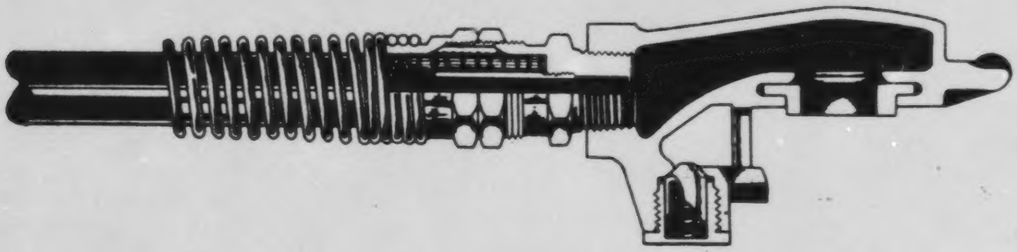
The LOW PRESSURE WARNING INDICATOR (fig. 10-45) is an electro-pneumatic switch connected with a warning buzzer or light. It remains open when air pressure is above approximately 60 pounds. When pressure drops below this point, the spring forces the diaphragm down and closes the contacts which operate the warning device. Normal operating pressure is 60 psi, plus or minus 6 pounds.

If the low pressure warning switch is worn or leaking, replace diaphragm or entire unit. If contact points are corroded, correct by filing with a fine file or sandpaper.

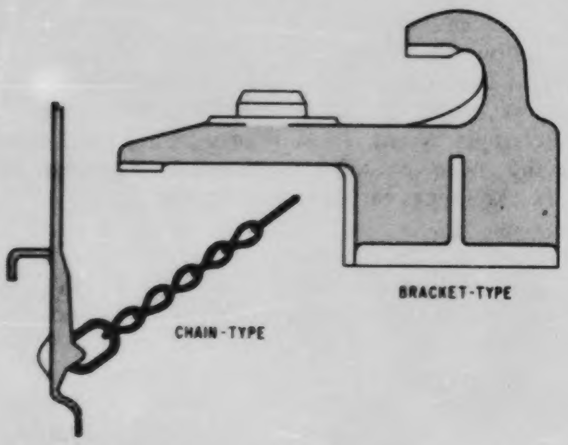
STOP LIGHT SWITCHES (fig. 10-46) are electro-pneumatic devices which operate in conjunction with the brake valve to close the stop light circuit when the brakes are applied. When air pressure from the brake valve enters the cavity on the one side of the diaphragm, the diaphragm changes its position, overcomes the force of the spring, and moves the contact plunger until the contacts close. This closes the stop light electrical circuit. The switch is designed to close as soon as 5 pounds air pressure is delivered to it. This means the stop light circuit closes immediately on a brake application.

SERVICING AIR BRAKES

Servicing is the most important part of air brake maintenance. If the airbrake system is kept clean, tight, and free of moisture, brake failures will be few and far between. Particular care must be taken to keep the air compressor intake filters clean, and foreign material out of the lines.

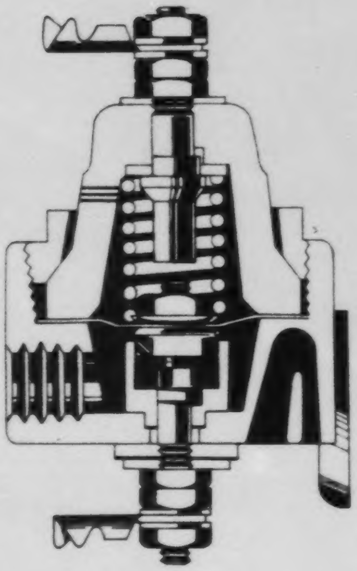


81.482
Figure 10-43.—Air hose and fittings.



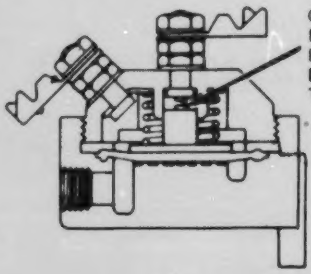
81.483

Figure 10-44.—Dummy couplings.



81.484

Figure 10-45.—Low pressure warning switch.



CHECK CONTACT POINTS FOR CORROSION OR PITING. CORRECT, IF NECESSARY, BY FILING CONTACT POINTS.

81.485

Figure 10-46.—Stop light switch.

The basic test made to an airbrake system is the operational test. This may be in the form of a road test or in the shop. During an operational test, the brakes are applied and released while observing for equal application, sluggish engagement or release, binding linkage, and exhaust of units. The operation of the emergency relay valve is checked by charging the trailer system and removing the emergency line. The brakes should engage when the line is removed and disengage when it is replaced. Before making any leakage or pressure tests, consult the manufacturer's specifications for correct pressure and maximum leakage.

To check the leakage of the overall system, fully charge the system, shut off the ignition, and observe the pressure drop on the gage mounted on the vehicle dash. The maximum leakage will be expressed in pounds per a specified time.

To determine if leakage of various units is within permissible or authorized limits, the soap suds test is used. To make this test, a thick mixture of soap suds is used. (Strong lye soap should not be used.) This mixture is applied to any place in the system where leakage may occur. While some places are authorized leakage, others are not. For example, castings and the tube in the governor should have no leakage. Points with authorized leakage will have a specified maximum in pounds per a specified time.

Soap suds can also be used to check the internal condition of a unit. By covering exhaust ports or casting openings, the condition of the diaphragms and valves can be checked. For example, to check the condition of the inlet valve of the brake valve, release the brakes and cover the exhaust port with soap suds. Leakage indicates the valve is not seating properly. To check the exhaust, the brake is engaged. If the diaphragm in the brake chamber is faulty, leakage will appear around the push rod with the brakes applied.

Always consult the manufacturer's specifications before making any adjustments. This is to ensure that the correct adjustment is made and that any variations in procedure are followed.

The linings used with air brakes gradually wear from use and require periodic adjustment or replacement. These linings are replaced using the same procedures discussed under riveted brake linings earlier in this chapter.

CHAPTER 11

CONSTRUCTION EQUIPMENT

Construction equipment used in the Navy is similar in many ways to the automotive vehicle. The size, weight, and design of this equipment causes its configuration to vary greatly, depending on its intended use. The power trains of the self-propelled equipment are similar to those of automotive vehicles, but are stronger to allow movement of heavy loads.

Stationary equipment is normally trailer or skid mounted. The trailer or skid serves as an operating platform to support the equipment once it is placed in position for operation.

This chapter describes the operating principles and functions of the following components of construction equipment: HYDRAULIC SYSTEMS, PLANETARY GEARS, PIVOT BRAKES, TRACK and TRACK FRAMES, POWER SHIFT and AUTOMATIC TRANSMISSIONS, WIRE ROPE and AIR COMPRESSORS.

HYDRAULIC SYSTEMS

In modern construction equipment, you will find hydraulic systems used to transmit power for steering and controlling the operation of mechanical components. The oil used in these systems is a special blend commonly referred to as HYDRAULIC FLUID.

HYDRAULIC FLUID

A hydraulic fluid must have the capacity to take on quickly the shape of its container. This capacity enables the fluid to be directed through a pipe or a hose by means of gravity or the force of a pump.

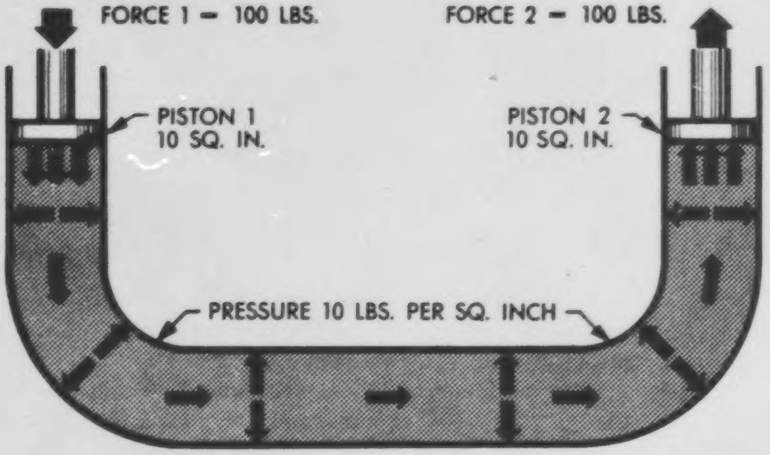
Hydraulic fluid must be able to lubricate the internal moving parts as it transmits force. In a large system, the pump moves a large volume of fluid under pressure that may reach 2,000 pounds per square inch (psi). This pressure, created by the resistance to flow, causes the fluid to become hot. As the temperature rises, the viscosity of the fluid tends to lower. Fluids used in a modern hydraulic system must be able to withstand high temperatures, and still provide the lubrication needed for closely mated parts of the system.

Hydraulic fluids are considered incompressible because of the relatively low pressure placed on the hydraulic fluid during operation in comparison to the amount needed to cause any noticeable change in volume. Pressures used in hydraulic systems are limited by two factors: the ability of the pump to pass fluid when under pressure and the strength of the containers of the hydraulic fluid.

TRANSMISSION OF FORCE

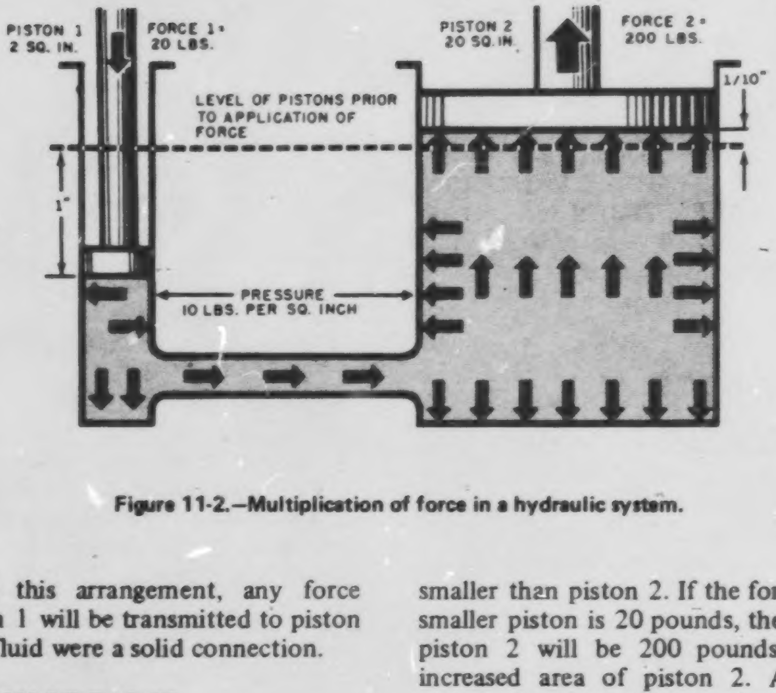
For a hydraulic system to transmit force, the system must be sealed to prevent leakage, it must provide a method of applying force to the fluid, and it must contain a movable component for the fluid to act upon.

As an example, notice in figure 11-1 that pressure is being applied equally to all portions of the system between the pistons. Piston 1 has 100 pounds of force applied to its surface. This force is measured as pressure. Notice that the same amount of force applied to piston 1 is transmitted through the fluid and applied to


FORCE 1 — 100 LBS.
FORCE 2 — 100 LBS.
PISTON 1
10 SQ. IN.
PISTON 2
10 SQ. IN.
PRESSURE 10 LBS. PER SQ. INCH

5.181

Figure 11-1.—Transmission of force in a hydraulic system.


PISTON 1
2 SQ. IN.
FORCE 1 = 20 LBS.
PISTON 2
20 SQ. IN.
FORCE 2 = 200 LBS.
1/10"
LEVEL OF PISTONS PRIOR TO APPLICATION OF FORCE
1"
PRESSURE
10 LBS. PER SQ. INCH

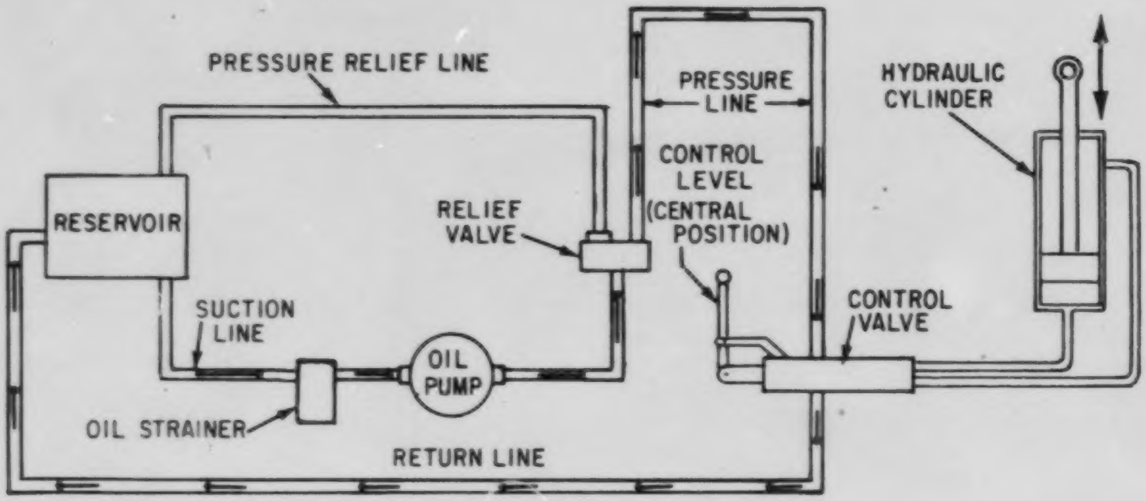
4.7

Figure 11-2.—Multiplication of force in a hydraulic system.

piston 2. With this arrangement, any force applied to piston 1 will be transmitted to piston 2 as though the fluid were a solid connection.

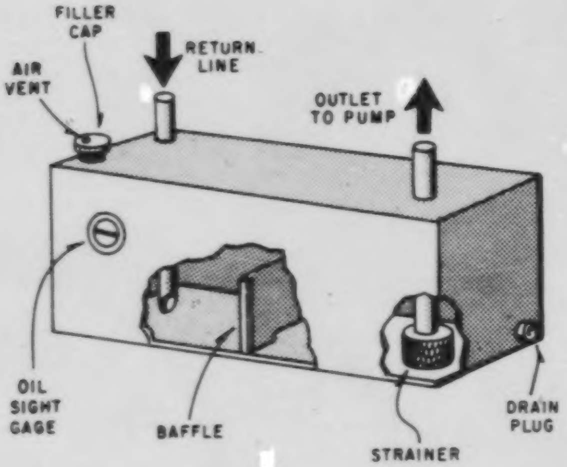
MULTIPLICATION OF FORCE

Some hydraulic systems are used to multiply force. In figure 11-2, notice that piston 1 is smaller than piston 2. If the force applied to the smaller piston is 20 pounds, the force applied to piston 2 will be 200 pounds because of the increased area of piston 2. Also notice that piston 1 moves farther than piston 2. This results in a mechanical advantage that depends on the volume of fluid and surface areas of the pistons.


PRESSURE RELIEF LINE
PRESSURE LINE
HYDRAULIC CYLINDER
CONTROL LEVEL (CENTRAL POSITION)
RESERVOIR
RELIEF VALVE
SUCTION LINE
CONTROL VALVE
OIL PUMP
OIL STRAINER
RETURN LINE

2.118

Figure 11-3.–A basic hydraulic system.


FILLER CAP
AIR VENT
RETURN LINE
OUTLET TO PUMP
OIL SIGHT GAGE
BAFFLE
STRAINER
DRAIN PLUG

81.566

Figure 11-4.–Typical hydraulic reservoir.

BASIC HYDRAULIC SYSTEM

A basic hydraulic system is illustrated in figure 11-3. This system consists of a RESERVOIR, STRAINER, POSITIVE DISPLACEMENT PUMP, VALVES and a HYDRAULIC CYLINDER interconnected by PIPING and HOSES. Other systems you may encounter will contain an ACCUMULATOR and a HYDRAULIC MOTOR in place of the hydraulic cylinder.

RESERVOIR

The reservoir illustrated in figure 11-4 contains many features that may be included in the ones you will find in hydraulic systems. This reservoir is usually located where it can readily dissipate heat to the atmosphere, cooling the hot fluid in the system. It must be large enough to allow for settling of any impurities and separation of air from the fluid prior to reuse in the system. All systems contain a vent for the reservoir that is either a part of the filler cap or mounted separately. The vent is located to prevent fluid loss and normally contains a filtering element. The filtering element keeps dirt from entering the system as the reservoir "breathes" due to temperature changes.

STRAINERS AND FILTERS

All hydraulic systems have a strainer and one or more filters to remove the impurities that would eventually contaminate the hydraulic fluid and render it useless. The strainer can be located in the reservoir, as illustrated in figure 11-4, or in the inlet line to the pump. A strainer is not as restrictive to flow as a filter.

Filters placed in suction lines that carry a large volume of fluid will cause a restriction. This restriction can reduce the volume of fluid being pumped and cause the pump to fail from lack of lubrication. A hydraulic pump should operate with a full volume of fluid at all times. When the pump inlet becomes restricted, air pockets develop inside the pump and may damage it. When installed in the return line of a system, a filter can remove pieces of metal, seals, and other unwanted matter before they reach the operating side of the system and damage closely mated parts.

The hydraulic filter is equipped with a valve that allows the fluid to bypass the filter element should it become clogged. The filter is normally located so that only a little fluid will be lost when the element is changed. Usually of the paper cartridge, cannister, or edge type, elements are similar to those used in engine lubrication systems. Regular filter maintenance is necessary to prevent contaminated fluid being recirculated in a system.

HYDRAULIC PUMPS

Pumps create the flow of fluid within a hydraulic system; they do not create pressure in the system. System pressure is caused by a restriction placed in the path of the fluid as it leaves the pump. Because of its mechanical drive and positive displacement, the pump merely moves the fluid regardless of the restriction. When enough pressure is built up, movement of the restriction occurs or a relief valve placed in the system opens, allowing the fluid to return to the reservoir or the suction side of the pump.

There are three types of hydraulic pumps: GEAR, VANE, and PISTON. The gear pump is commonly used on construction equipment.

The gear pump illustrated in figure 11-5 has a fixed displacement. This means that a measured amount of fluid is passed with each revolution of the pump regardless of speed. Gear pumps have two gears in mesh, closely fitted inside a housing. A drive shaft turns one gear, which in turn drives the other gear. Internal seals and machined surfaces or wear plates are used to seal the turning gears and prevent excessive leakage.

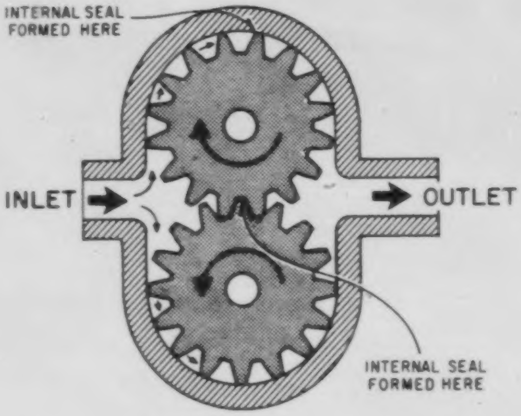
When the pump operates, oil is trapped between the gear teeth and the pump housing. The trapped oil is carried to the outlet side of the pump. As the teeth mesh, a seal is formed by the mating surfaces and prevents the oil from leaking back to the inlet side of the pump. The sealing action causes the oil to be forced out of the pump and into the system.

VALVES

The valves in a hydraulic system control pressure, and direct or limit the flow of fluid to the operating components.

Relief Valves

A relief valve must be used with the positive displacement pump to prevent excessive pressure in the hydraulic system. Too much pressure could result in damage to the components of the system and injury to operating personnel.



81.567

Figure 11-5.—Fixed displacement gear pump.

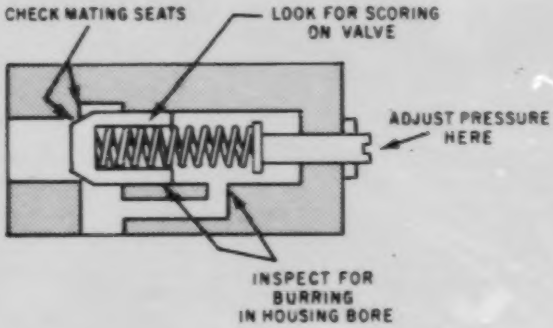
The pressure relief valve illustrated in figure 11-6 is adjustable. Pressure within the system is maintained by tension of the spring. When the pressure exceeds the spring's tension, the valve opens and allows the fluid to return to the reservoir or the suction side of the hydraulic pump. A relief valve may be installed as illustrated in figure 11-3 or as component of the pump or control valve.

Control Valves

Control valves are valves accessible to the operator for directing the flow of fluid within the system to operate the machine or its attachments. By skillful use of the control valves, the operator can regulate the speed and operation of hydraulic cylinders. Hydraulic controls should be operated smoothly to eliminate the jerking motion that causes rapid wear and failure of the mechanical parts of the machine.

The open center control valve (fig. 11-7) is the type commonly used with a positive displacement pump. This valve provides a direct return of fluid to the reservoir when the valve is in the neutral position.

A closed center valve is used with nonpositive displacement pumps because it blocks the return of fluid when in the neutral position. This type of control valve will direct the fluid to either end of the cylinder.


CHECK MATING SEATS
LOOK FOR SCORING ON VALVE
ADJUST PRESSURE HERE
INSPECT FOR BURRING IN HOUSING BORE

81.568
Figure 11-6.–Adjustable pressure relief valve.

HYDRAULIC CYLINDERS

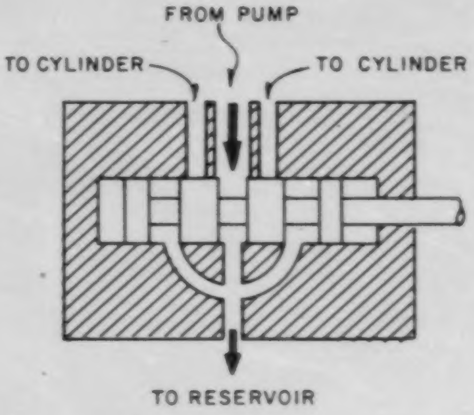
Hydraulic cylinders are used to transmit motion in relation to the volume of fluid directed into the cylinder. The force created by the cylinder is determined by the pressure of the fluid and the area of the piston contacted by the fluid. Thus, the larger the piston, the more force generated.

As mentioned earlier, the pressure of a hydraulic system may reach 2,000 psi. If this pressure is applied to a cylinder which has a piston diameter of four inches, the resulting force would be more than 25,000 pounds.

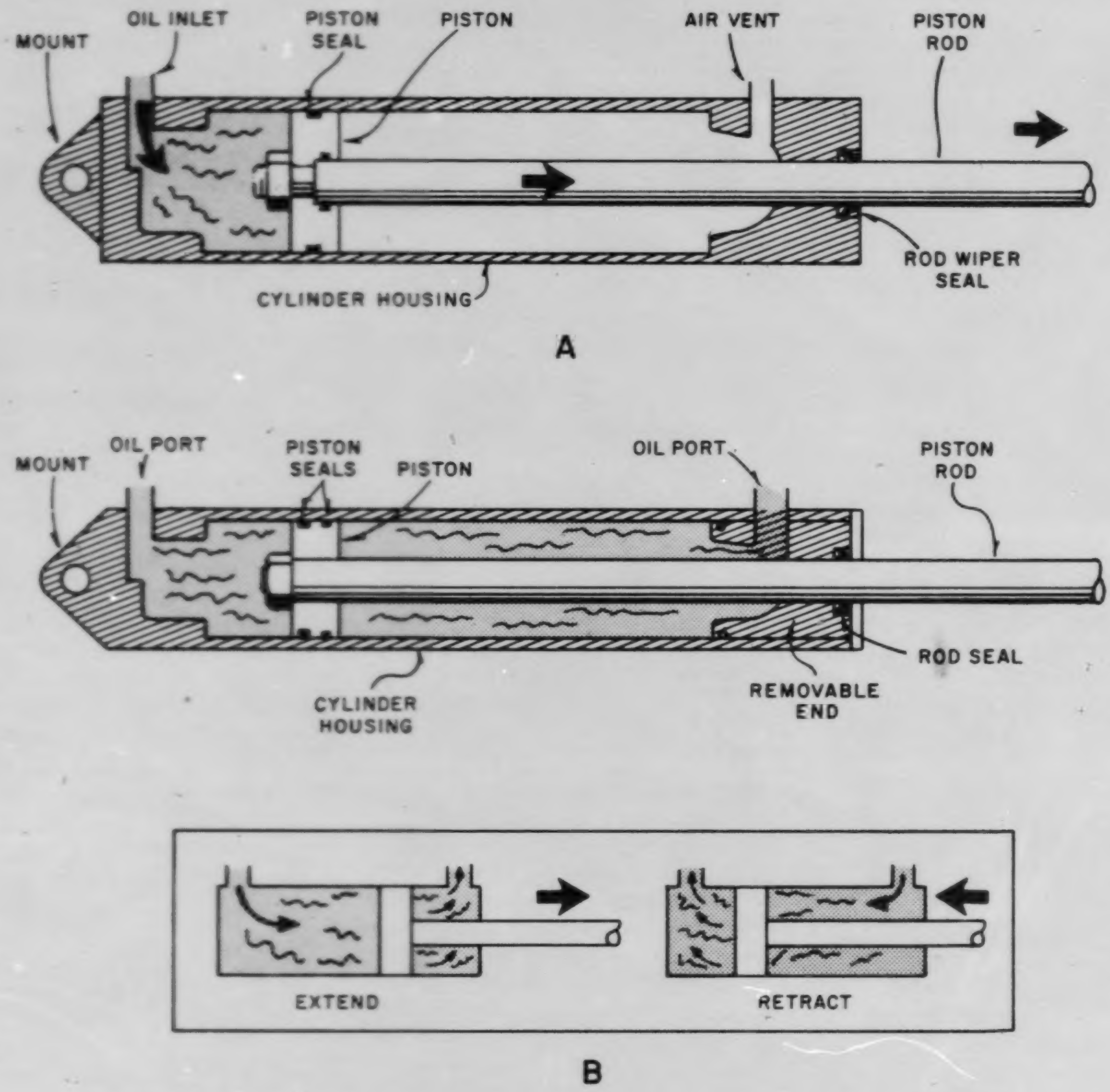
Hydraulic cylinders used on construction and materials handling equipment are either single- or double-acting.

Single-Acting Cylinders

Single-acting cylinders similar to the one illustrated in figure 11-8 are used to exert force in only one direction. This means that the weight or resistance moved must be located so that it will cause the cylinder to return to its original position when pressure is relieved from the piston. In some applications, springs are added to help retract the piston rod. A common use of this type of cylinder is in the hydraulic jack found in the maintenance shop.



81.569
Figure 11-7.–Simplified drawing of an open center hydraulic control valve.


MOUNT
OIL INLET
PISTON SEAL
PISTON
AIR VENT
PISTON ROD
ROD WIPER SEAL
CYLINDER HOUSING
A
MOUNT
OIL PORT
PISTON SEALS
PISTON
OIL PORT
PISTON ROD
ROD SEAL
REMOVABLE END
CYLINDER HOUSING
EXTEND
RETRACT
B

81.570

Figure 11-8.—(A) Single- and (B) double-acting hydraulic cylinders.

Double-Acting Cylinders

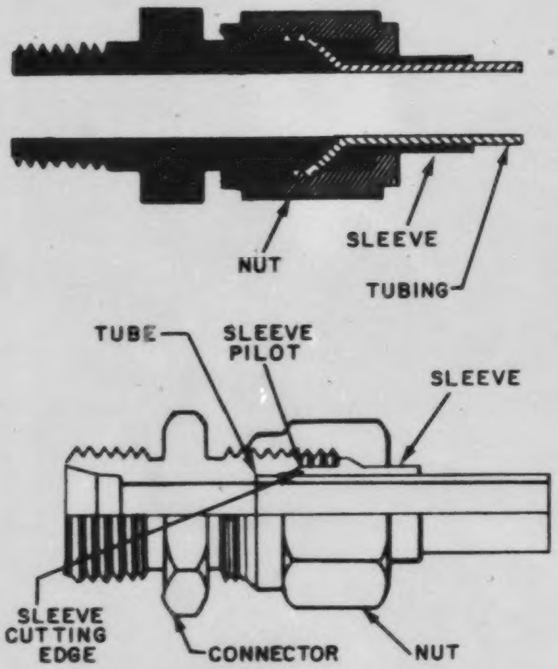
Double-acting cylinders like the one in figure 11-3 are used on equipment where force is needed in two directions. Unlike the single-acting cylinder, the double-acting cylinder contains seals at both ends of the piston and where the piston rod passes through the end of the cylinder. With the use of this cylinder, fluid can be directed to either side of the piston and cause the piston rod to extend or retract under pressure. The double-acting cylinder shown in figure 11-8 is called an unbalanced cylinder. This means that the cylinder can exert more force in one direction than in the other. This is due to the piston rod preventing fluid from acting on the full area of the piston on one side.

TUBING, PIPING, HOSES AND FITTINGS

The piping and hoses used in a hydraulic system must withstand the maximum pressure of that system. Special tubing, piping, and hoses are used in the hydraulic system to withstand this pressure and make the system reliable and safe to operate.

Tubing

The tubing in a hydraulic system is seldom over 1 inch in diameter. Tubing connections (fig. 11-9) can be flared or flareless and resemble those used with copper tubing. Two types of tubing are in use: seamless and welded.



194.57:61

Figure 11-9.—Fittings commonly found on tubing in hydraulic systems.

Tubing is preferred to pipe because it bends easily, reducing the number of pieces and fittings. The additional advantages of cutting and flaring in the field for on-the-job repairs make tubing more suitable than pipe. In general, tubing is neater, less costly, and easy to maintain. Also, there are fewer restrictions and less chance of leakage with tubing.

Piping

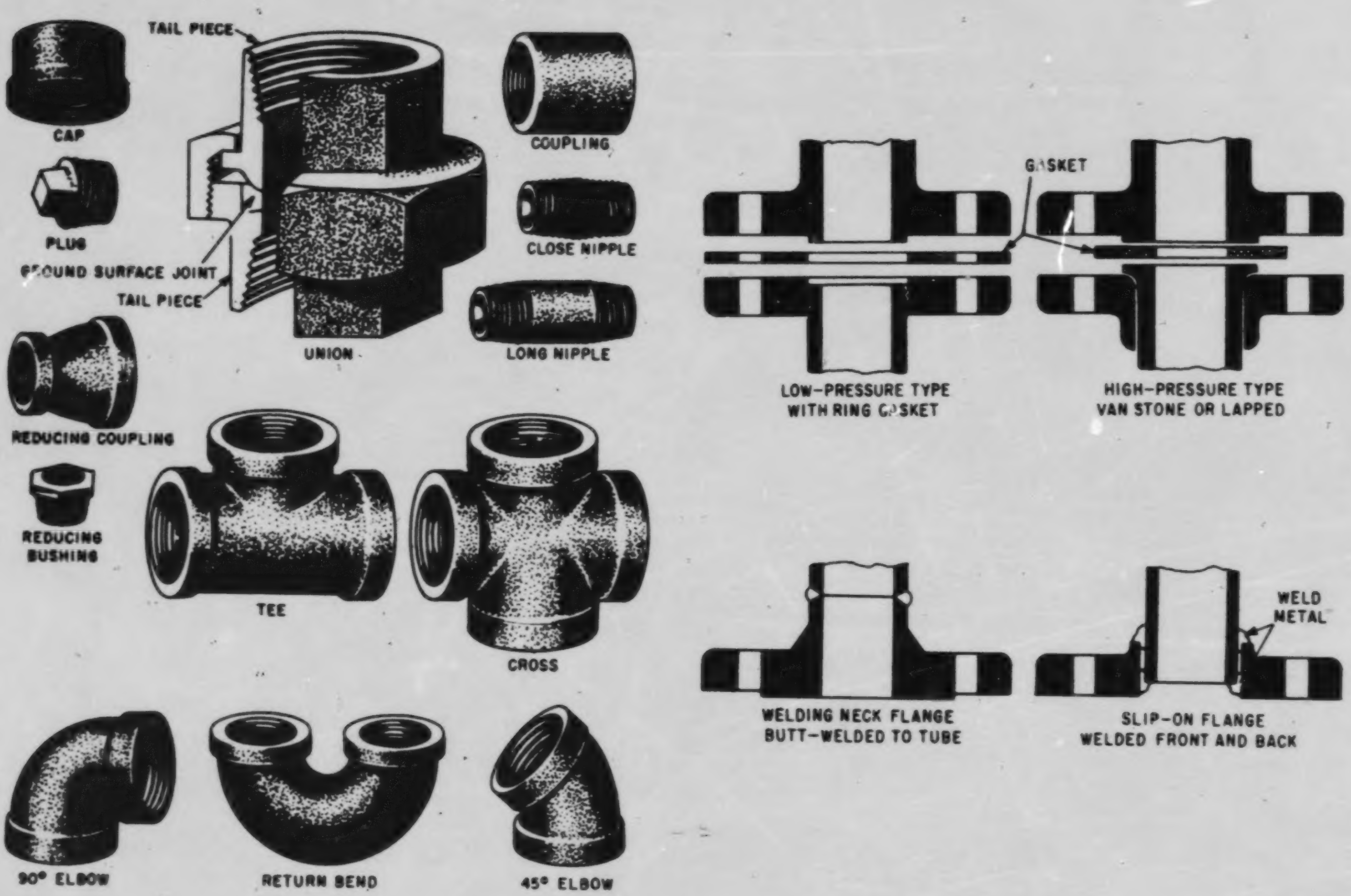
Pipe is preferred in systems which move large volumes of fluid over straightline distances. Bending of pipe is not recommended. Fittings are needed with pipe to make joints or detour around obstructions.

Pipe with threaded fittings up to 1 1/4 inch in diameter is suitable in systems where pressures are less than 1,000 psi. In systems that require higher pressure or larger pipe, welded flanged connections are installed. Common pipe connections are shown in figure 11-10.

Hoses and Fittings

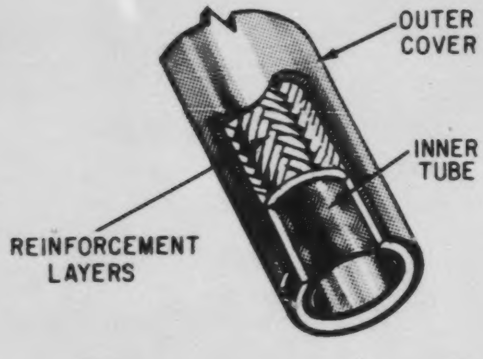
Flexible hoses and fittings are used in a hydraulic system to allow movement between mechanical parts of the equipment. Hoses are manufactured in layers (See fig. 11-11.) The inner layer is made of synthetic material that resists deterioration from the fluid in the system. The middle layer or layers are made of either fabric or rubber for low pressure systems, or wire braid for high pressure applications. These layers give the hose its strength. Fabric layers are normally limited to two in number and wire braid to five. The outer layer of the hose provides a protective covering to prevent damage to the middle layer(s).

Fittings for high pressure hoses are made of forged steel. They are usually not replaceable unless changed since the equipment was manufactured. Those shown in figure 11-12 are of the replaceable type and are used to make a replacement hose should one fail during use.


TAIL PIECE
CAP
PLUG
GROUND SURFACE JOINT
TAIL PIECE
UNION
COUPLING
CLOSE NIPPLE
LONG NIPPLE
REDUCING COUPLING
REDUCING BUSHING
TEE
CROSS
90° ELBOW
RETURN BEND
45° ELBOW
GASKET
LOW-PRESSURE TYPE
WITH RING GASKET
HIGH-PRESSURE TYPE
VAN STONE OR LAPPED
WELD
METAL
WELDING NECK FLANGE
BUTT-WELDED TO TUBE
SLIP-ON FLANGE
WELDED FRONT AND BACK

194.51:54

Figure 11-10.—Pipe connections used in hydraulic systems.



81.571

Figure 11-11.–Hydraulic hose construction.

ACCUMULATORS

Accumulators are sometimes placed in a hydraulic system to absorb shock. These are frequently used on tracked front end loaders and other equipment containing hydraulic systems that are subjected to severe shock.

The accumulator is a large cylinder which contains compressed gas or a coil spring separated from the hydraulic fluid by a piston, rubber bladder, or diaphragm. When a heavy shock is placed on the hydraulic system, fluid enters the cylinder and causes the gas or spring to compress. Once the shock load stabilizes within the hydraulic system, the fluid is forced back onto the operating portion of the system.

HYDRAULIC MOTORS

Hydraulic motors provide power to winches on cranes, drive conveyors on ditching machines, and are used in other applications where mechanical drives would be impractical.

The hydraulic motor is turned by fluid, under pressure supplied by the pump. The fluid enters the housing and acts on the rotating members. Fluid then discharges and returns to the reservoir or pump. Fluid passes through the motor in the same manner that it does in the pump, the difference being that the fluid moves the rotating parts of the motor.

Hydraulic motors often contain components identical to those in a pump. The gear and piston types are widely used on construction equipment.

HYDRAULIC SYSTEM MAINTENANCE

Maintenance of a hydraulic system that is properly operated and cared for is a routine task. This usually consists of changing or cleaning filters and strainers, and occasionally adding or changing the fluid in the hydraulic system. However, an improperly operated system can be damaged by overheating, excessive pressure, and contamination.

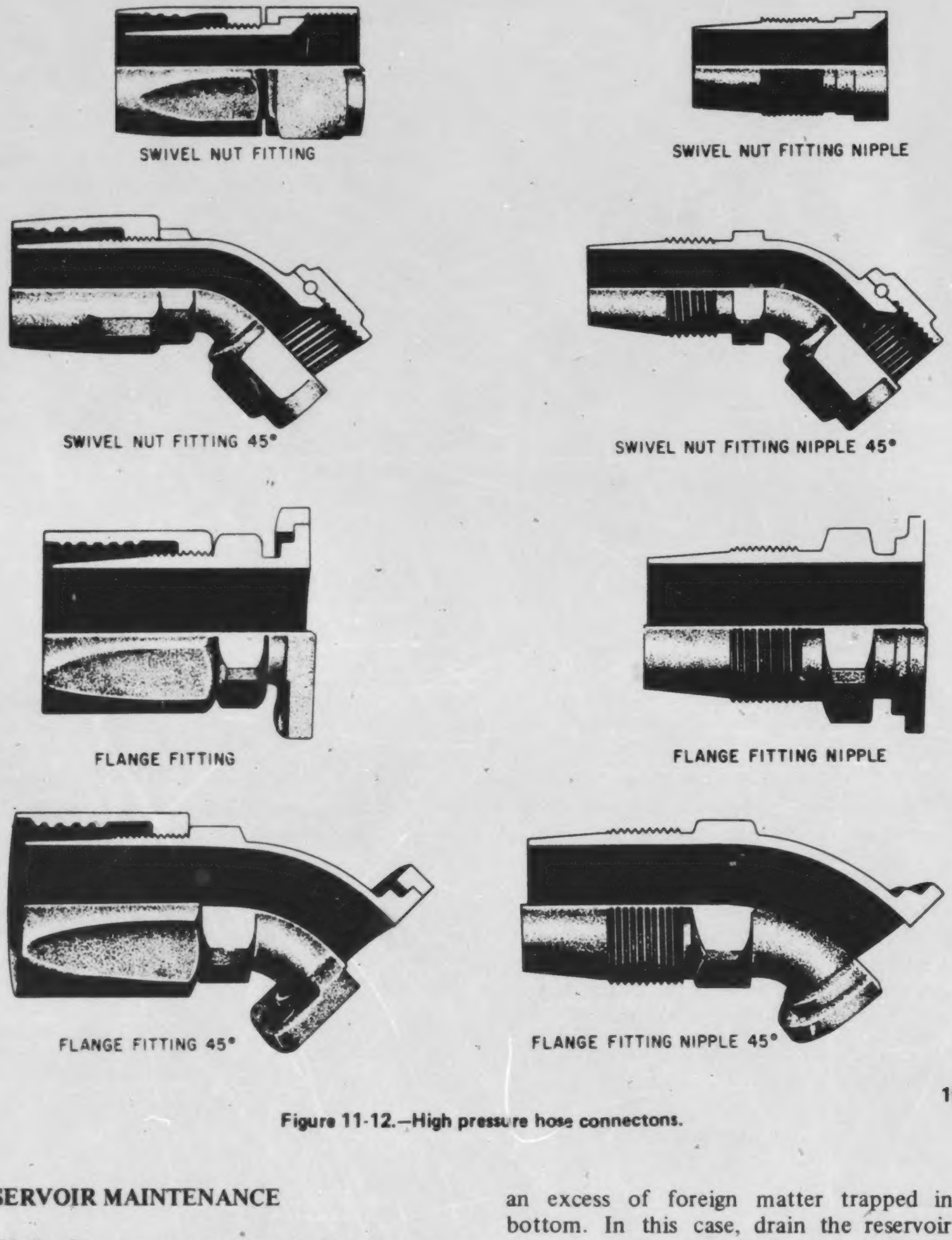
Hydraulic fluid must have special lubricating and anti-foaming qualities. It must be low in viscosity and able to withstand the effects of extreme operating temperatures. When adding or changing fluid, use only the fluid recommended by the manufacturer.

When working on a hydraulic system, you must consider cleanliness an important factor. Small dirt and metal particles can score valves and clog orifices, resulting in major repair work. Before servicing a component of the system, remove any exterior dirt and oil from the component. In steam cleaning the system, make sure all openings are blocked so that no water can enter. Once parts are removed, plug the hydraulic connections to keep out dirt. This is especially important when the equipment is being repaired in the field or placed on deadline for extended periods of time.

After all parts are removed and disassembled, clean them. If they are not to be replaced soon after cleaning, cover them with rags to keep dirt and dust away.

FILTER MAINTENANCE

Regular filter changes are required to insure solid particles are removed from the system. Filters remove foreign particles from the fluid that circulate in the system. Hydraulic filters require changing on a scheduled basis. They should be changed more often under adverse operating conditions. When changing filters, thoroughly clean the filter housing before installing a new filter. Remember to add enough fluid to compensate for any fluid lost in filter replacement.



SWIVEL NUT FITTING

SWIVEL NUT FITTING NIPPLE

SWIVEL NUT FITTING 45°

SWIVEL NUT FITTING NIPPLE 45°

FLANGE FITTING

FLANGE FITTING NIPPLE

FLANGE FITTING 45°

FLANGE FITTING NIPPLE 45°

194.63

Figure 11-12.—High pressure hose connectons.

RESERVOIR MAINTENANCE

If the filters become clogged often between changes, the frequency of filter changes is not adequate. It is also possible that the reservoir has an excess of foreign matter trapped in the bottom. In this case, drain the reservoir and clean it. Many manufacturers recommend flushing of the hydraulic system periodically to prevent an accumulation of foreign matter.

Usually, new fluid is added to the system after it is flushed or drained.

REPAIRING LEAKS

Leaking hydraulic connections are frequent reasons for maintenance. Some leaks are external, being evident on the outsides of components. Others are internal; they are not visible and must be located by testing.

External Leakage

External leaks not only cause cleaning problems but make it hazardous for operators of equipment. A leak that allows floor plates to become slippery may cause the operator to fall on or off the equipment and get injured. A leak that drips on hot engine parts may start a fire that could result in the loss of the equipment.

Cylinders may leak around piston rods or rams. You may repair some leaks by tightening the packing located in the cylinder end cap. Tighten the packing evenly until only a light film of fluid is noticeable on the rod when it is extended. DON'T overtighten; this results in rapid failure of the packing and may cause scoring of the rod. If you find an internal seal instead of packing, the cylinder must be removed and disassembled to stop the leak.

Leaks often arise from hoses that deteriorate and rupture under pressure. Such a leak is usually first noticed after hydraulic fluid is found beneath equipment that has remained idle for some time.

Figures 11-13 and 11-14 show the proper procedures for repairing hoses with reusable fittings. You can remove a medium or high pressure hose from its fittings by unscrewing the nipple from the socket and then the socket from the hose.

If you find a hose whose outer covering has been trimmed back where it enters the fitting, replace the fitting and hose as shown in figure 11-14. The fitting, called a "non-skive" fitting is the only one authorized for use on Navy equipment.

Sometimes you can stop leaks at fittings by tightening the hose connections. Tighten them only enough to stop the leakage. If you cannot stop a leak by tightening, secure the equipment and remove the connection. Place a drip pan beneath the connection to catch fluid left in the hose. Plug the connection on the equipment to keep out foreign matter. Inspect the threaded and mating parts of the connector. Look for cracks in the flared ends of tubing. Examine the O-rings found in some connections and replace if defective.

Here are some hints that will help reduce maintenance of hoses.

Leave a little slack in a hose between connections to allow for swelling when pressure is applied to the hose. A taut hose is likely to pull out of its fittings.

Don't loop a hose unless its manufacturer calls for looping. This causes unnecessary flexing of the hose as pressure changes. Angled fittings should be used instead of loops.

Don't twist a hose; twisting causes the hoses to weaken.

Use clamps or brackets to keep a hose away from moving parts or to prevent chafing when the hose flexes.

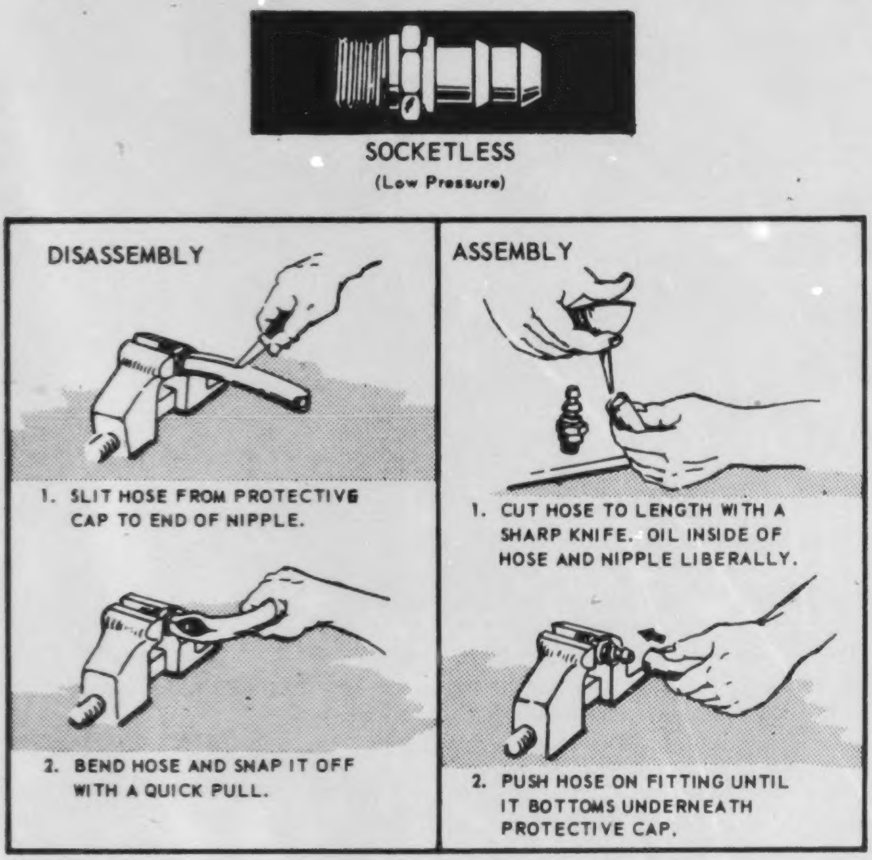
Keep hoses away from hot surfaces, such as manifolds and exhaust systems. If unable to do so, install a heat shield to protect the hose.

Try to route hoses so there are no sharp bends in them. This is more critical with high pressure hoses than low pressure hoses.

Internal Leakage

A small amount of internal leakage is allowed to provide lubrication of moving parts. This leakage is normal and does not result in faulty operation.

On the other hand, an excess of internal leakage results in slow operation, loss of power, and overheating of the hydraulic fluid. The cylinders may creep or drift and, if the leak is bad enough, the control valves may not function properly.


SOCKETLESS
(Low Pressure)
DISASSEMBLY
1. SLIT HOSE FROM PROTECTIVE CAP TO END OF NIPPLE.
2. BEND HOSE AND SNAP IT OFF WITH A QUICK PULL.
ASSEMBLY
1. CUT HOSE TO LENGTH WITH A SHARP KNIFE. OIL INSIDE OF HOSE AND NIPPLE LIBERALLY.
2. PUSH HOSE ON FITTING UNTIL IT BOTTOMS UNDERNEATH PROTECTIVE CAP.

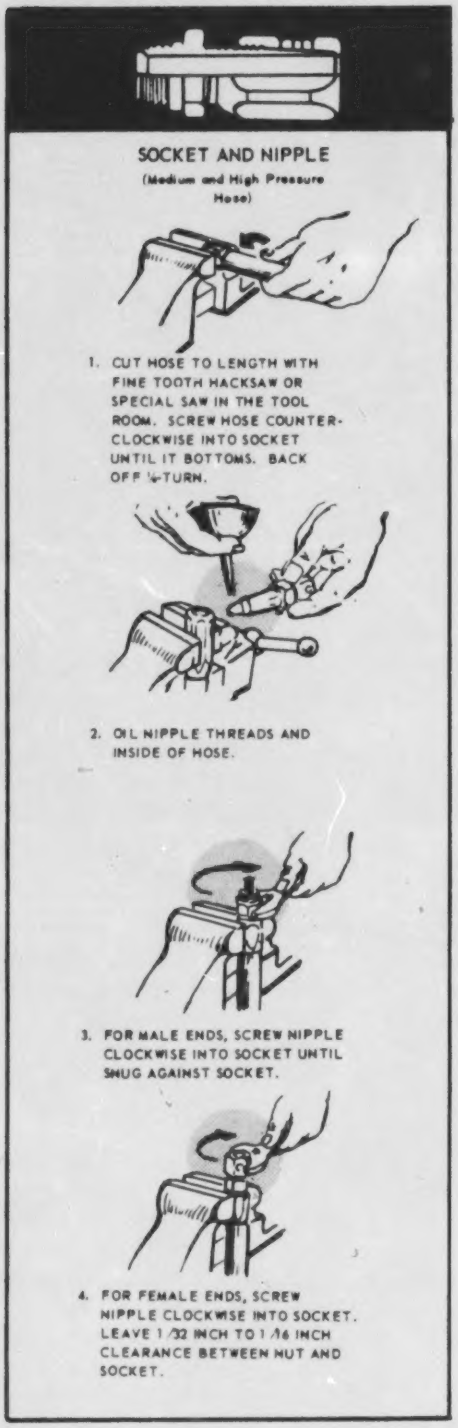
81.572

Figure 11-13.—Replacing low pressure hose on a reusable fitting.

Internal leaks are caused by wear of the seals and mating parts during normal operation. These leaks are often difficult to locate. Usually, all you can do is observe the operation of the system for signs of sluggishness, creeping, and drifting. When these signs appear, you must test the system to pinpoint the problem.

If you suspect a cylinder or control valve to be faulty, extend the cylinder to place it under load and move the control valve to neutral. Secure the engine. If the load settles or drifts faster than recommended by the manufacturer, block the load. Now disconnect the return line from the control valve to the reservoir and plug the line. Remove the support from the load and check for excessive leakage at the control valve. If this occurs, the valve must be removed and replaced. Control valves are normally sealed at the ends of the spool only, and internal leakage is a sign of an excessively worn valve body and/or spool. These valves are not repairable in the maintenance shop.

If no leakage is evident at the valve, the cylinder should be checked unless it is a single-acting cylinder which leaks externally through the breather hole when the piston seal becomes faulty. To check a double-acting cylinder, extend/retract the cylinder and block in position. Place the control valve in neutral, and secure the engine. Remove the line that is connected to the cylinder end not under pressure. Start the engine and apply pressure to the same side of the cylinder to extend/retract as before and look for evidence of leaking. If none occurs, repeat the procedure on the other



SOCKET AND NIPPLE
(Medium and High Pressure Hose)

1. CUT HOSE TO LENGTH WITH FINE TOOTH HACKSAW OR SPECIAL SAW IN THE TOOL ROOM. SCREW HOSE COUNTER-CLOCKWISE INTO SOCKET UNTIL IT BOTTOMS. BACK OFF ¼-TURN.
2. OIL NIPPLE THREADS AND INSIDE OF HOSE.
3. FOR MALE ENDS, SCREW NIPPLE CLOCKWISE INTO SOCKET UNTIL SNUG AGAINST SOCKET.
4. FOR FEMALE ENDS, SCREW NIPPLE CLOCKWISE INTO SOCKET. LEAVE 1/32 INCH TO 1/16 INCH CLEARANCE BETWEEN NUT AND SOCKET.

81.573

Figure 11-14.–Replacement procedures for medium and high pressure hose with reusable fittings.

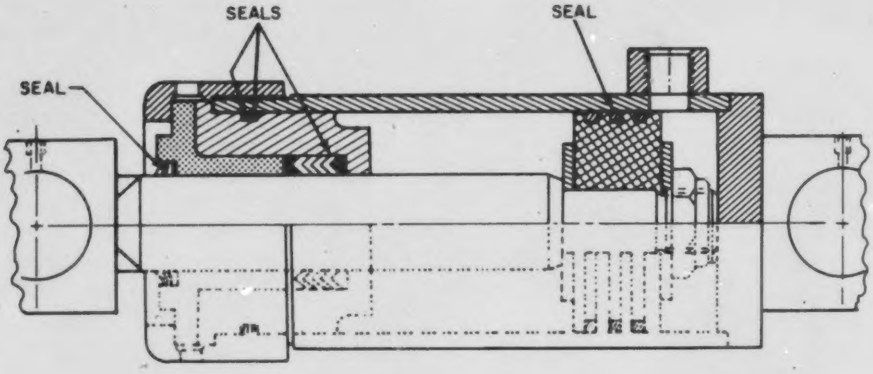
end of the cylinder. Double-acting cylinders may leak when operated in one direction but not the other.

To repair a faulty cylinder, you must remove the cylinder assembly. Once removed, take the cylinder to a clean working area for disassembly. Clean and inspect the parts for scoring or other damage. If in doubt as to the condition of any parts, see the maintenance manual or your supervisor for advice. When the cylinder is ready for reassembly, install new seals on the piston and between the mating parts of the cylinder assembly. Figure 11-15 illustrates the location of seals in a typical hydraulic cylinder. Replacing a rod seal in the cylinder end cap is sometimes difficult but necessary to prevent rework. The seals are usually available in kits from the parts room. Install these seals carefully to prevent damage that will cause faulty operation of the ram. It's a good idea to coat the inside of the cylinder with fluid before installing the piston. This practice will help to prevent damage to the piston seal and also lessen the force necessary to install it. After reassembly, use an air hose to check the operation of the cylinder before replacing on the equipment.

Should you find two cylinders that work together, like the blade rams on a bulldozer, overhaul both cylinders at the same time if possible. This will insure that the blade or other attachment will lower and raise evenly.

If the hydraulic system operates in a slow, jerking manner and excessive noise is present, the problem is usually caused by a small hole in the suction side of the pump allowing air to enter the pump. The air causes voids within the fluid and results in noise when the aerated fluid is flowing or being compressed within the pump. A thorough check first thing in the morning before the machine is operated will usually make this problem visible as a fluid leak in the inlet side of the pump supply line.

When you have slow response under all operating conditions and no unusual noise, it is time to get the manufacturer's manual and a high pressure gage. Access is provided for attaching the gage in the high pressure system at the pump or control valve on many types of hydraulic systems. Others with a separate relief valve will provide access at the valve for connecting the gage. Using an adapter, install the gage as indicated by the manufacturer, and start



81.574

Figure 11-15.—Location of seals in a typical hydraulic cylinder.

the equipment. If you are unable to observe the gage from the operator's position, have someone assist you. Any valve except the blade control valve on a bulldozer, or one that contains cylinders with piston poppets can be used. Move the valve to the operating position and allow the device being actuated to reach the end of its travel. Continue to hold the valve for enough time to get a maximum reading from the gage. This will indicate the maximum pressure of the system. By comparing this reading with the one the manufacturer recommends, you can determine if the relief valve needs adjustment. Never adjust the relief valve without a gage and the manufacturer's specifications. If unable to adjust the pressure high enough, remove the relief valve for inspection to insure that it is functioning properly and that no seals or moving parts of the valve are damaged. If no fault is located within the valve, reinstall it and remove the hydraulic pump. The pump can be worn enough that internal leakage is excessive, preventing the development of adequate pressure in the system. The pump, like the control valve, is not repairable except for replacement of the seals and bearings.

Accumulators seldom fail during operation. Should a failure occur, replacement of the seals, diaphragm, or rubber bladder will return it to usable condition.

Hydraulic motors are subjected to operating conditions similar to a pump's. Overhaul of a hydraulic motor is limited to the replacement of seals and bearings.

POWER SHIFT AND AUTOMATIC TRANSMISSIONS

Most of the fundamentals of hydraulics are put to use in one form or another in torque converters and power shift or automatic transmissions. The design of these units will vary, depending on their application. In general, a power shift or automatic transmission is used in conjunction with a torque converter and shifting is accomplished hydraulically when the range selector lever is moved by the operator.

FLUID COUPLING AND TORQUE CONVERTER OPERATION

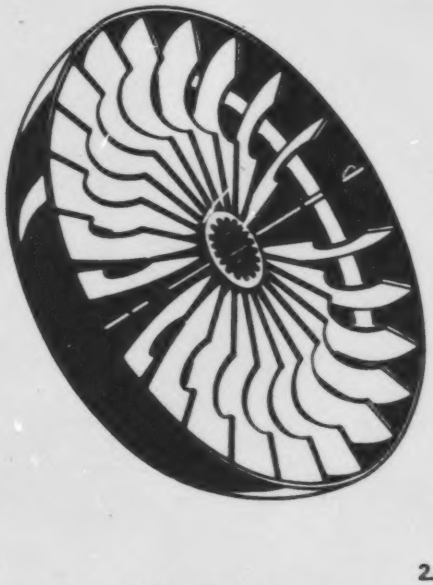
The torque converter is a refined version of the fluid coupling. Although the fluid coupling does not multiply torque, the torque converter actually increases the torque provided by the power source.

The fluid coupling consists of two members—a pump and a turbine. They are placed close together inside a housing filled with oil. The pump is connected to an engine and the turbine is connected to the remainder of the drive train. Both members contain many blades that are used to pump the oil or react from the force of the oil as the engine accelerates or decelerates.

As an example of how the fluid coupling works, place two fans facing each other on a table and turn one on. You will see the second fan start to turn as a result of the air striking its blades. This is the principle by which the fluid coupling works.

The blades of the pump and turbine inside a fluid coupling are straight, as illustrated in figure 11-16. When the engine is running, oil is thrown outward from the center of the pump and strikes the outer end of the turbine blades. As engine speed is increased, the force of the oil striking the turbine blades increases, causing the turbine to turn. Because of the design, slippage is high, resulting in an undesirable power loss. For this reason, a true 1:1 drive ratio is never achieved. As the engine slows, the vehicle's momentum causes the turbine to attempt to drive the pump. However, slippage is so great that a free wheeling effect will occur below speeds of approximately 20 mph and the engine's compression has little, if any, effect on slowing the vehicle.

Improvements in design of the fluid coupling led to the use of curved blades and the addition of a third member, the stator. The improved design (fig. 11-17) enabled torque from the engine to increase when the vehicle was stationary or picking up speed under acceleration. The redesigned blade directed oil from the pump to the turbine blades at a greater angle, allowing the full force of the oil to act on the turbine. In addition, the stator redirected the oil returning from the turbine so that it struck the blades of the pump in the direction of rotation. The velocity of the returning oil added to that of the oil leaving the pump. The improvements made the fluid coupling increase the torque provided by the engine. Hence, the name TORQUE MULTIPLIER or TORQUE CONVERTER.



2.204X

Figure 11-16.—Fluid drive pump.

Many designs of torque converters are in use today, and each has a minimum of three members. Some slippage is always present and has the desirable effect of keeping the engine from stalling at idle speeds or when the engine's power is insufficient to move the vehicle when loaded.

HYDRAULIC TORQUE CONVERTER

The hydraulic torque converter assembly illustrated in figure 11-18 is used on the International Harvester TD-20 series B tractor and model 250 series B loader. The converter contained in the assembly automatically varies the output required at the tracks to meet the changing load requirements of the tractor. Engine power is transferred by the converter with little change in torque when the load is light. Under heavy load, the torque multiplication increases, but with a resulting loss of tractor speed. Although the converter does not increase engine horsepower, it makes more torque available at the tracks.

The converter portion of the assembly has three basic parts: impeller, stator, and turbine. The IMPELLER (pump) is bolted to the converter drive housing which is driven by the engine flywheel. The STATOR is splined to the stationary ground sleeve hub and contains a row of stationary blades, sometimes called guide blades or reactor blades. The TURBINE is splined to the output shaft. The three parts are contained in the converter housing which is filled with fluid held at a constant pressure of 50 to 80 psi during operation to suppress vacuum pockets which form at the blades under high fluid velocities. There is no direct mechanical connection between the impeller and turbine or stator.

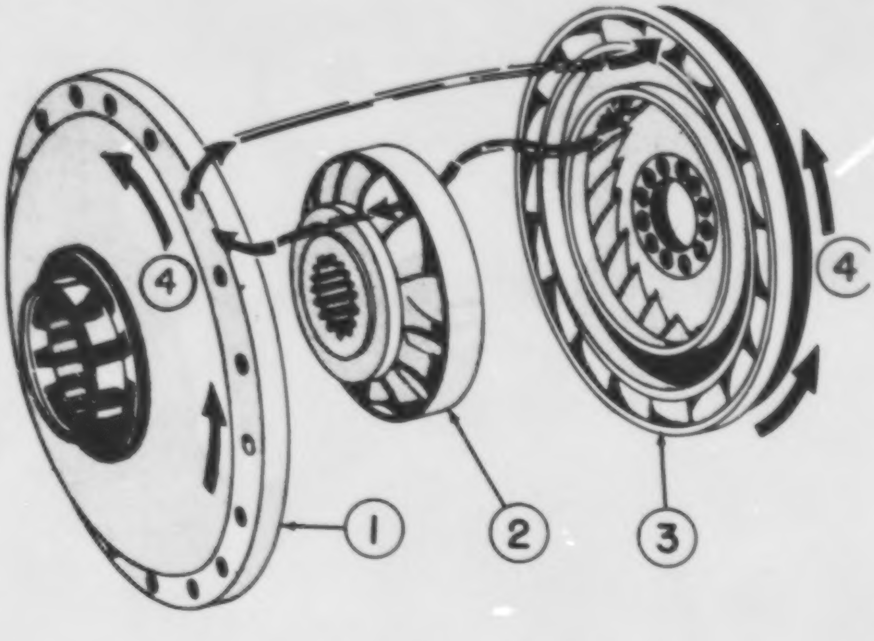
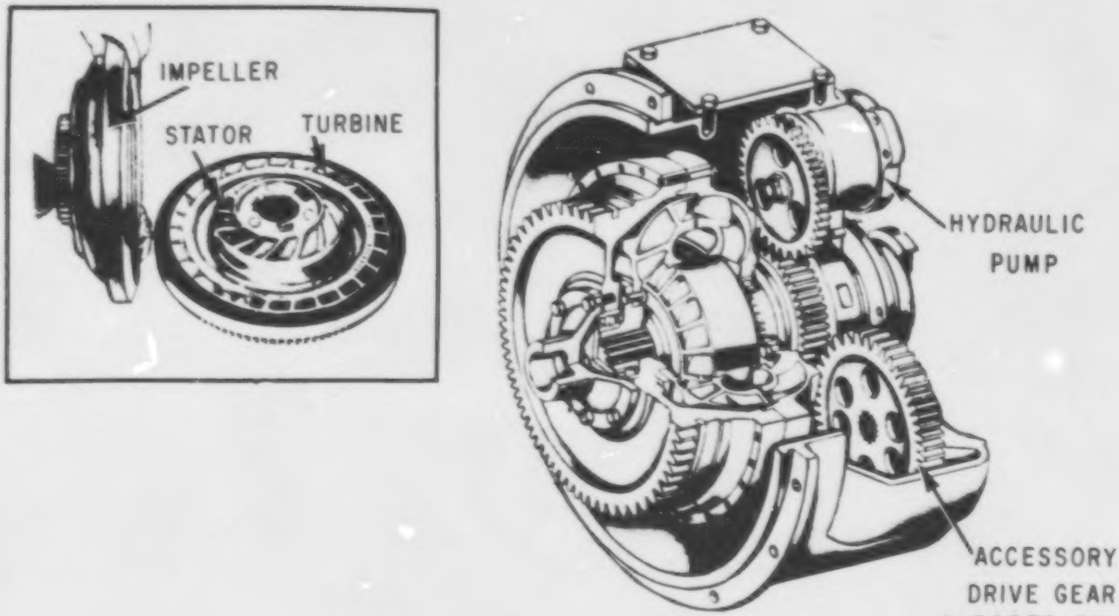


Figure 11-17.—Flow of oil through converter vanes.

81.378


IMPELLER
STATOR
TURBINE
HYDRAULIC PUMP
ACCESSORY DRIVE GEAR (LOADER ONLY)

2.427

Figure 11-18.—Torque converter.

The impeller draws fluid from the opening surrounding the hub and ejects it from its blades at high velocity. The turbine is positioned opposite the impeller, and its blades receive the full impact of this velocity. Fluid exits from the turbine in the opposite direction of rotation from that of the impeller. Then the curved blades of the stator (positioned between the impeller and turbine) redirect the flow back to the impeller in the same direction as the impeller is moving. (See fig. 11-17.)

Torque multiplication is determined by the speed of the turbine in relation to impeller speed. A ball thrown at a paddle will strike it with more force if the paddle is stationary rather than moving in the same direction as the ball. Similarly, when the turbine is rotating as fast as the impeller, the fluid passes easily through the turbine, applying little or no force to the blades. As the output shaft slows down, the fluid strikes the turbine blades with more force. The maximum striking force of the fluid is reached when the turbine is stopped. This occurs in a tractor when the output shaft is stalled by a heavy load.

The reservoir for this torque converters fluid is in the rear main frame of the tractor. The flow from the reservoir to the converter and from the converter back into the lubricating system is described later in this chapter. The troubleshooting chart of table 11-1 will aid you in locating and correcting mechanical problems in the International Harvester (TD-20 series B tractor and model 250 series B loaders) hydraulic torque converter.

POWER SHIFT TRANSMISSIONS

The International Harvester power shift transmission (fig. 11-19) is used with the torque converter just described. It is designed to provide high speed shifting through hydraulically actuated clutches. The transmission has two forward and two reverse speeds in both low and high ranges. Shifting from one range to another is controlled by the hi-lo shifting lever mounted on the transmission front cover.

The transmission is coupled to the torque converter by a universal joint. Gears are mounted on four shafts: the reverse clutch shaft, the forward clutch shaft, the spline shaft, and the bevel pinion shaft.

The bevel pinion shaft consists of the high and low range gears which are keyed to the shaft

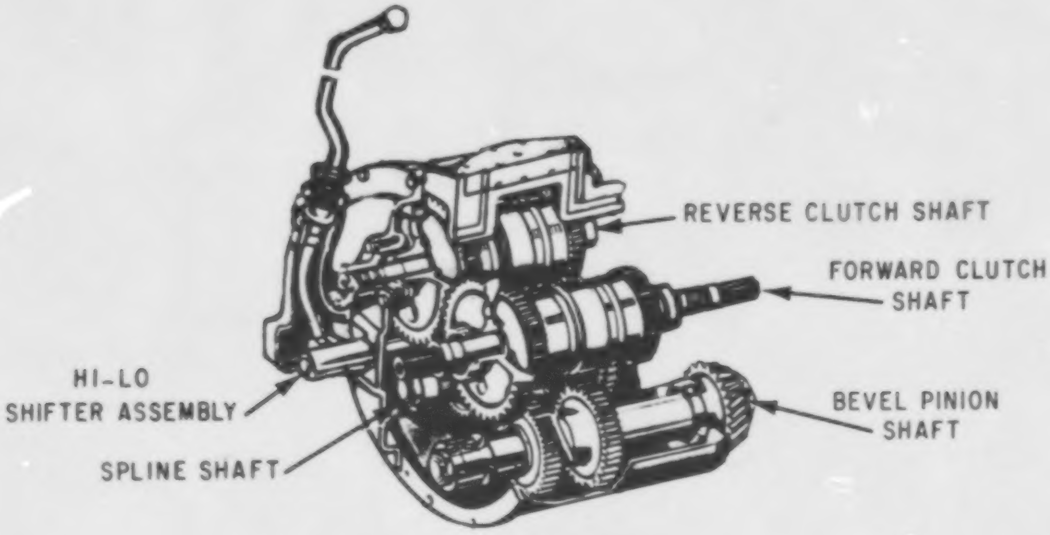


Figure 11-19.–Power shift transmission.

Table 11-1.—Troubleshooting Chart for International Harvester (TD-20 Series B Tractor and Model 250 Series B Loaders) Hydraulic Torque Converter

Trouble	Possible Causes	Corrective Measures
Loss of fluid from torque converter.	Leaking connections.	Operate the engine at part throttle and inspect all lines and connections for leaks. Tighten or replace parts as necessary.
	Leaking converter.	Check all bolts and nuts and gasket joints while the system is under pressure. Replace parts as necessary.
Torque converter overheating.	Operating too long in low efficiency ranges.	Review operating instructions in the operator's manual.
	Low basic pressure.	Check for broken lines or loose connections on the pressure side of the system. Check for excessive fluid leaking.
	Low oil level.	Check the level in the rear main frame.
	Thermo bypass valve inoperative (if equipped).	Remove and add parts to operate the hydraulic system without a thermo bypass valve.
	Converter bypass valve sticking.	Remove valve and clean. Inspect bore and spring.
Loss of power.	Low oil level.	Check the level in the rear main frame.
	Low basic pressure.	Check for broken lines or loose connections on the pressure side of the system. Check for excessive fluid leaking.
	Converter input pump inoperative.	Inspect pump for damaged parts and replace as necessary.
	Converter bypass valve sticking.	Remove valve and clean. Inspect bore and spring.
	Engine not up to rated performance.	Refer to engine service manual.
Grinding or scraping noise inside converter housing.	Bearing failure allowing the turbine or impeller blades to strike the fixed stator.	Replace bearings, turbine, or impeller as necessary.

81.575

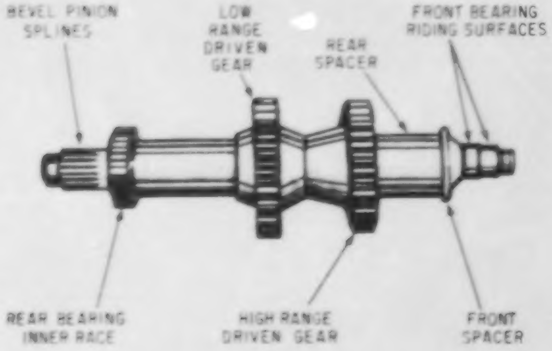
(fig. 11-20). The shaft is supported at the rear by a straight roller bearing, and at the front by a double-row taper roller bearing. The pinion gear is splined to the rear of the pinion shaft and held in place by a nut. A shim pack is provided between the front bearing cage and the transmission case front cover for adjusting pinion depth.

The spline shaft, shown in figure 11-21 rotates on two straight roller bearings. The rear bearing is mounted in the transmission case, the front bearing in the transmission cover. The first and second speed driven gears are held in position on the spline shaft by snap rings and are constantly meshed with the first and second speed drive gears on the clutch shafts. The hi-lo driving gear slides freely on the shaft and drives the bevel pinion shaft when brought into mesh with either the high or low range driven gear by means of the hi-lo shifting lever.

The FORWARD CLUTCH SHAFT, shown in figure 11-22, rotates on a straight roller bearing at the rear and ball bearing at the front. The REVERSE CLUTCH SHAFT, shown in figure 11-23, has a straight roller bearing at each end. The reverse drive gear is keyed to the front of the forward clutch shaft, and the reverse driven gear is keyed to the front of the reverse clutch shaft. Each shaft consists of first and second speed drive gears which ride on bushings and are welded to the dual hydraulic clutch pack assemblies.

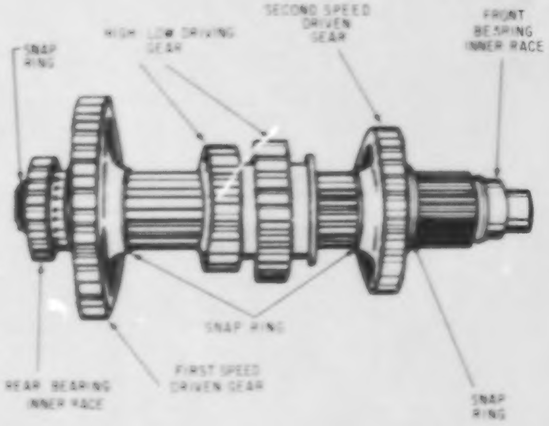
Forward and Reverse Hydraulic Clutch Operation

The forward and reverse hydraulic clutch is actually two clutches on a common shaft with a common apply force piston between them. The


BEVEL PINION SPLINES
LOW RANGE DRIVEN GEAR
REAR SPACER
FRONT BEARING RIDING SURFACES
REAR BEARING INNER RACE
HIGH RANGE DRIVEN GEAR
FRONT SPACER

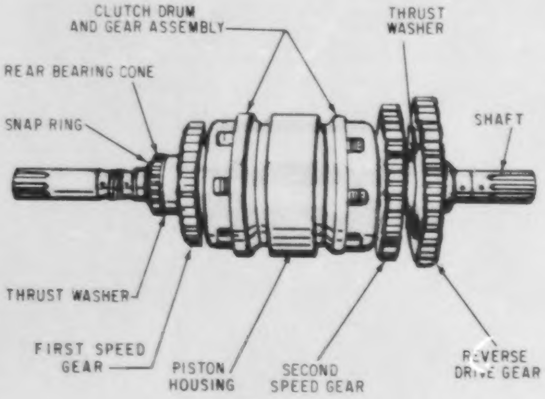
2.429

Figure 11-20.—Bevel pinion shaft.


SNAP RING
HIGH LOW DRIVING GEAR
SECOND SPEED DRIVEN GEAR
FRONT BEARING INNER RACE
SNAP RING
REAR BEARING INNER RACE
FIRST SPEED DRIVEN GEAR
SNAP RING

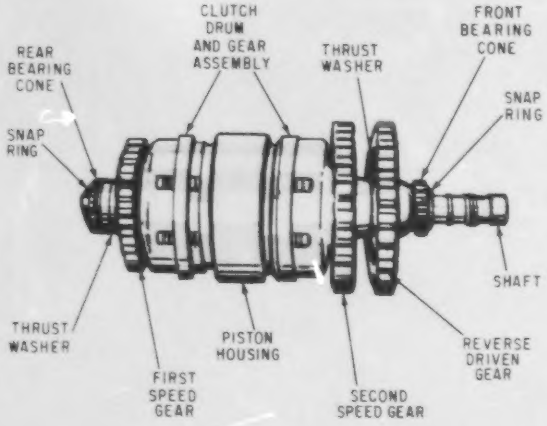
2.430

Figure 11-21.—Spline shaft.


CLUTCH DRUM AND GEAR ASSEMBLY
THRUST WASHER
REAR BEARING CONE
SNAP RING
SHAFT
THRUST WASHER
FIRST SPEED GEAR
PISTON HOUSING
SECOND SPEED GEAR
REVERSE DRIVE GEAR

2.431

Figure 11-22.—Forward clutch shaft.


REAR BEARING CONE
CLUTCH DRUM AND GEAR ASSEMBLY
THRUST WASHER
FRONT BEARING CONE
SNAP RING
SNAP RING
SHAFT
THRUST WASHER
PISTON HOUSING
FIRST SPEED GEAR
SECOND SPEED GEAR
REVERSE DRIVEN GEAR

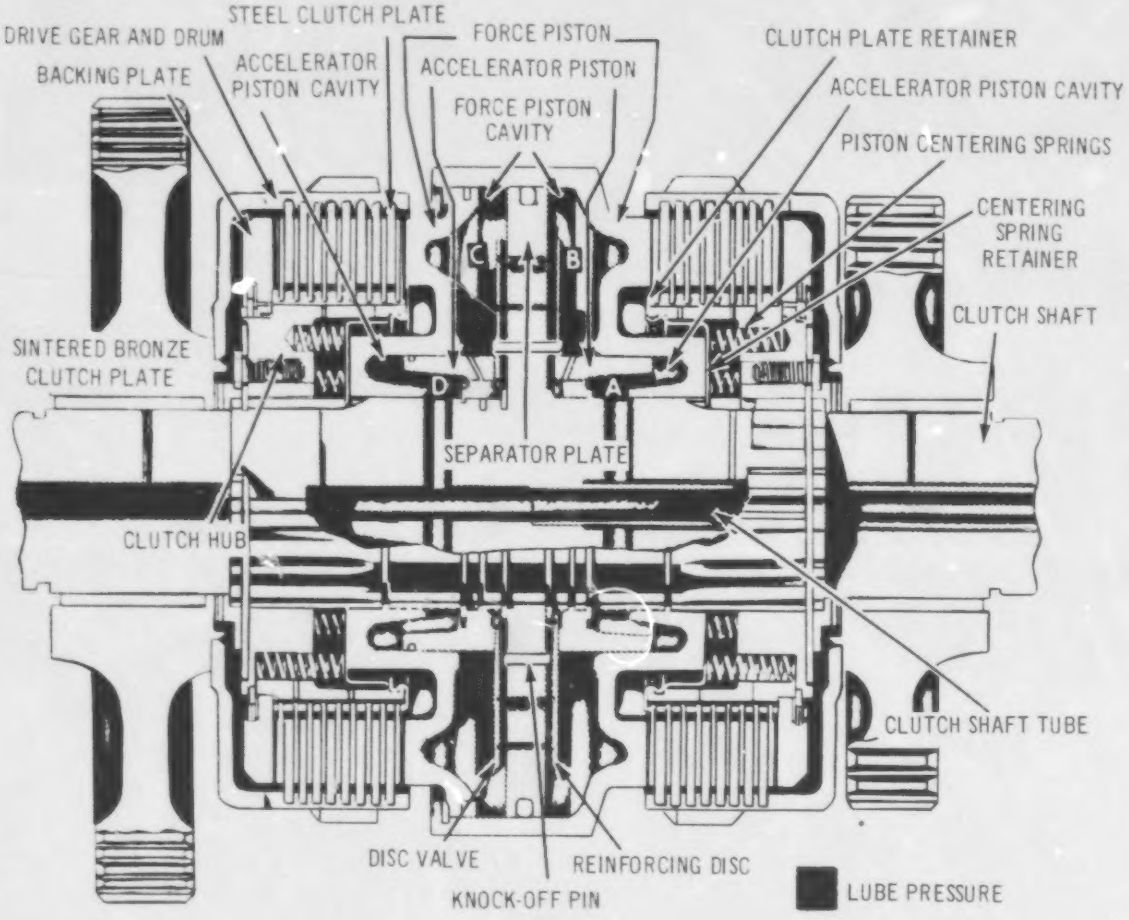
2.432

Figure 11-23.—Reverse clutch shaft.

clutches allow the simple transfer of oil from the disengaged clutch into the cavity created by the engaging clutch. This allows a low volume of main pressure to actuate the clutch for high speed shifting.

The heart of the clutch is contained in two pistons—the accelerator piston and the force piston. Pump oil volume is not needed to fill the applying clutch cavity, and only a relatively low volume is needed to pressurize the clutch. In neutral, all accelerator and force piston cavities are filled with oil at lube pressure (10 to 25 psi). A selector valve, located on the top of the transmission case, directs the oil to the accelerator piston cavities and, in turn, to the force piston cavities. Once the pistons are filled with oil, they remain full under lube pressure. Other small cross-drilled passages furnish a constant supply of lube oil to the drive gear bushing, the drum assemblies, and the clutch hubs for distribution through the clutch plates. In neutral, neither clutch is engaged, the drive gear and drum assemblies are free and no torque is transmitted through the clutch, as shown in figure 11-24.

Upon application of the clutch, main oil pressure (approximately 200-230 psi) is directed through the clutch shaft for the specific side of the clutch desired. The oil enters the force


STEEL CLUTCH PLATE
DRIVE GEAR AND DRUM
BACKING PLATE
ACCELERATOR PISTON CAVITY
FORCE PISTON
ACCELERATOR PISTON
FORCE PISTON CAVITY
CLUTCH PLATE RETAINER
ACCELERATOR PISTON CAVITY
PISTON CENTERING SPRINGS
CENTERING SPRING RETAINER
CLUTCH SHAFT
C
B
D
A
SINTERED BRONZE CLUTCH PLATE
SEPARATOR PLATE
CLUTCH HUB
CLUTCH SHAFT TUBE
DISC VALVE
REINFORCING DISC
KNOCK-OFF PIN
LUBE PRESSURE

2.433

Figure 11-24.—Flow of oil through clutch in neutral position.

piston cavity and causes the clutch to engage (fig. 11-25). When engaged, the clutch holds the gear stationary in relation to the shaft. Power then flows from the shaft, via the clutch, to the gear.

When the transmission is returned to neutral, an immediate pressure drop occurs within the disengaging accelerator piston cavity and the compressed piston centering springs return the common apply force piston to its centered position or neutral.

Gear Shifter Mechanism

On older models, the gearshift lever, located on the left-hand side of the operator, is connected through linkage to the range selector valve assembly on the top of the transmission case. Movement of the gearshift lever positions the selector valve to allow main oil pressure to engage the clutch desired as illustrated by the hydraulic flow diagram in figure 11-26.

In today's models, the lever is connected to the range selector valve by hydraulic lines. A spool valve (pilot control valve) actuated by the gearshift lever directs main pressure to the range selector valve and causes it to direct main pressure to the desired clutch assembly, as illustrated in figure 11-27.

The hi-lo shifting lever (on the transmission front cover) is held in position by a poppet lock in the hi-lo shifting housing. To shift from one range to another, the engine must be running and the gearshift lever must be in neutral position. This allows main oil pressure from the pump to pass through a drilled hole in the pilot valve and through an oil line to the shifter housing. Here it releases the poppet lock to enable shifting.

The troubleshooting chart of table 11-2 will help you determine possible causes of transmission malfunctions and corrective measures for repairing the troubles.

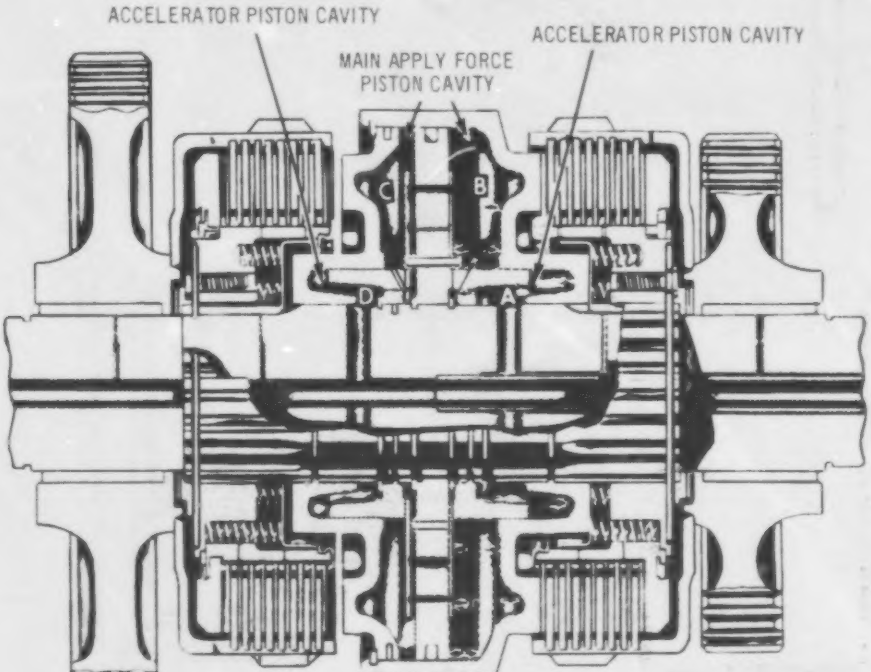

ACCELERATOR PISTON CAVITY
MAIN APPLY FORCE PISTON CAVITY
ACCELERATOR PISTON CAVITY
C
B
D
A
MAIN PRESSURE
LUBE PRESSURE
2.435

Figure 11-25.—Flow of oil through clutch in engaged position.

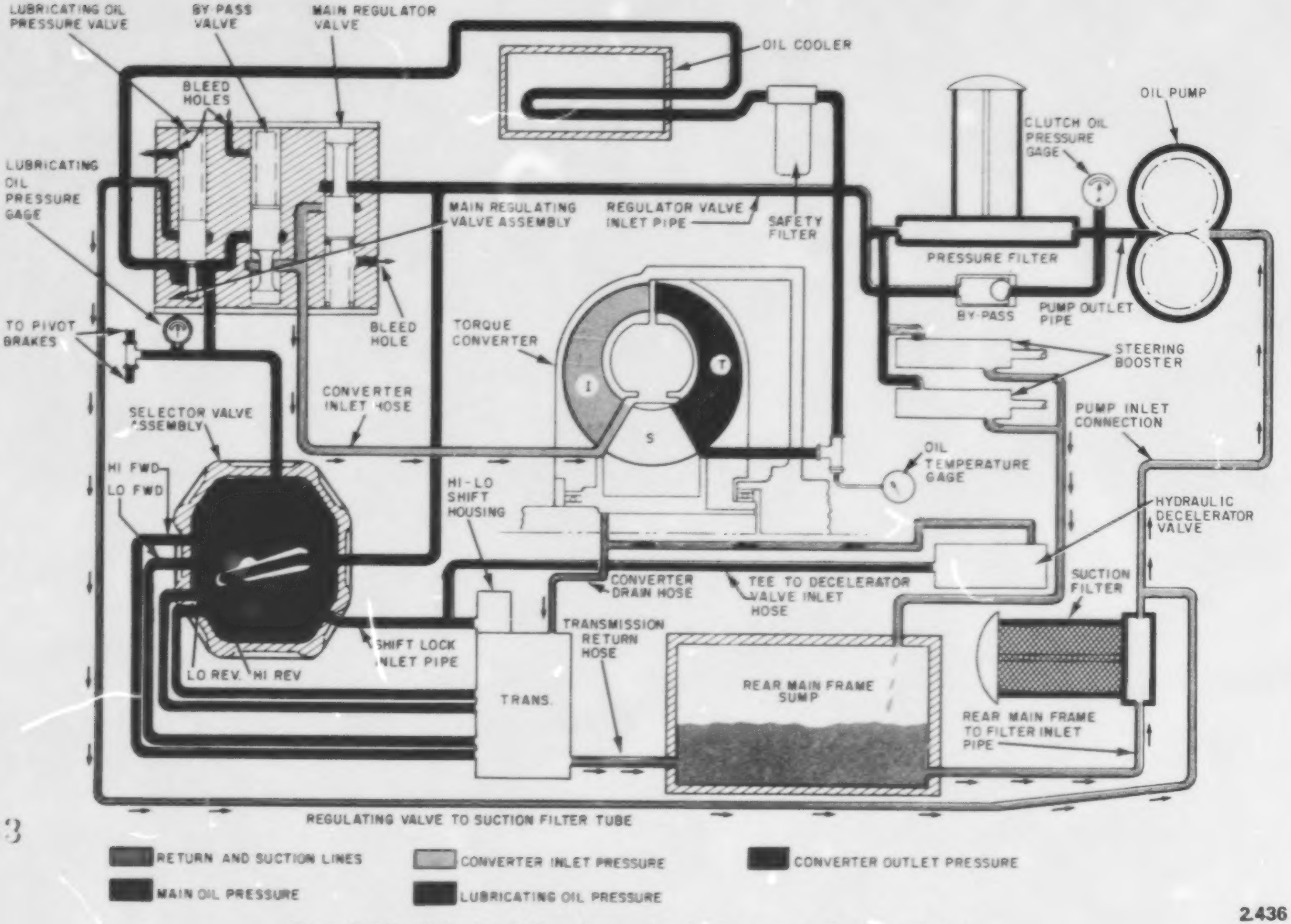
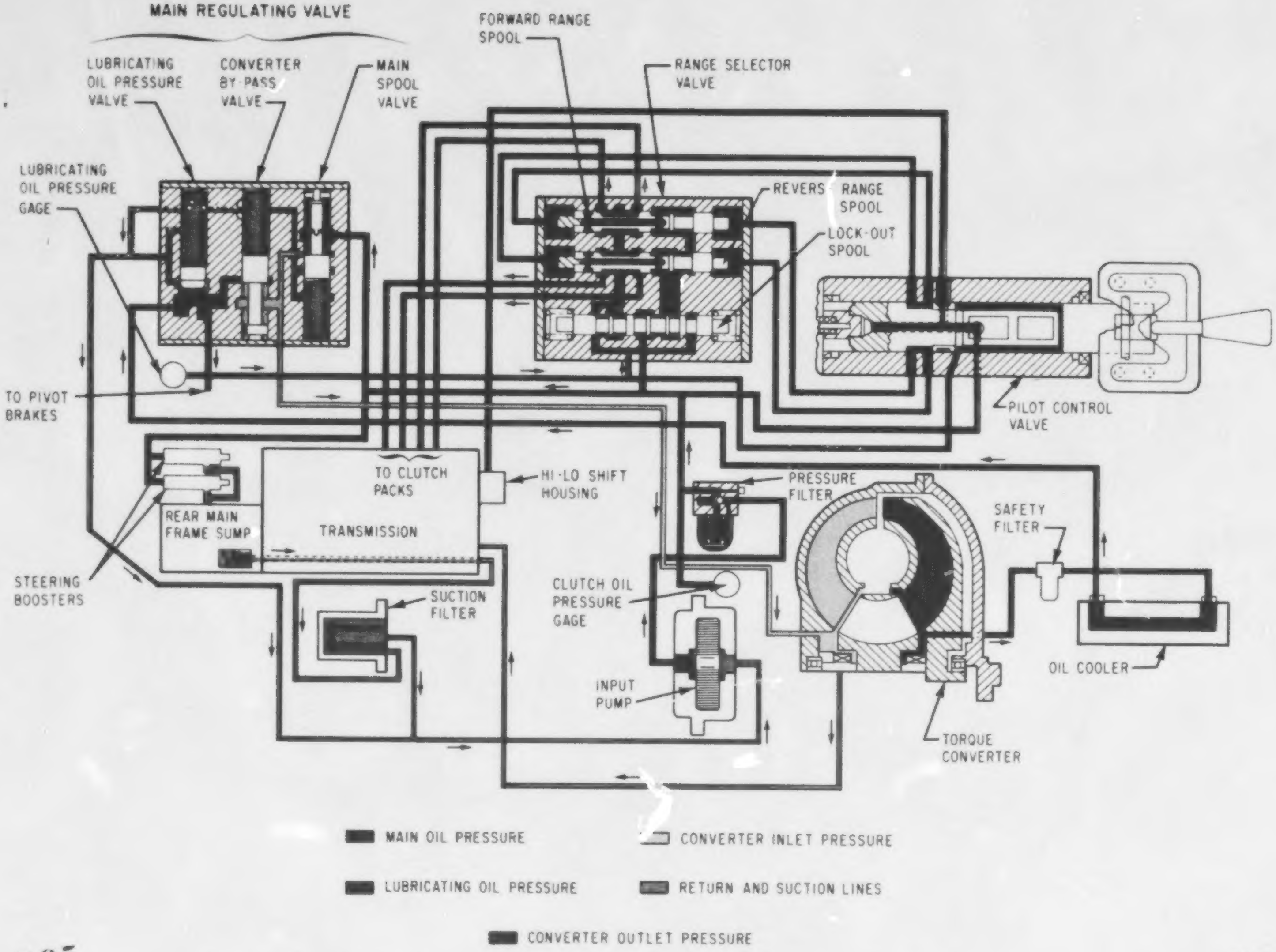

LUBRICATING OIL PRESSURE VALVE
BY-PASS VALVE
MAIN REGULATOR VALVE
OIL COOLER
BLEED HOLES
LUBRICATING OIL PRESSURE GAGE
MAIN REGULATING VALVE ASSEMBLY
REGULATOR VALVE INLET PIPE
SAFETY FILTER
CLUTCH OIL PRESSURE GAGE
OIL PUMP
PRESSURE FILTER
BY-PASS
PUMP OUTLET PIPE
TO PIVOT BRAKES
BLEED HOLE
TORQUE CONVERTER
I
T
S
STEERING BOOSTER
SELECTOR VALVE ASSEMBLY
CONVERTER INLET HOSE
PUMP INLET CONNECTION
HI FWD
LO FWD
OIL TEMPERATURE GAGE
HI-LO SHIFT HOUSING
HYDRAULIC DECELERATOR VALVE
CONVERTER DRAIN HOSE
TEE TO DECELERATOR VALVE INLET HOSE
SUCTION FILTER
SHIFT LOCK INLET PIPE
TRANSMISSION RETURN HOSE
LO REV.
HI REV
TRANS.
REAR MAIN FRAME SUMP
REAR MAIN FRAME TO FILTER INLET PIPE
REGULATING VALVE TO SUCTION FILTER TUBE
RETURN AND SUCTION LINES
CONVERTER INLET PRESSURE
CONVERTER OUTLET PRESSURE
MAIN OIL PRESSURE
LUBRICATING OIL PRESSURE
2.436

Figure 11-26.--Hydraulic oil flow diagram (mechanically controlled transmission).


MAIN REGULATING VALVE
LUBRICATING OIL PRESSURE VALVE
CONVERTER BY-PASS VALVE
MAIN SPOOL VALVE
LUBRICATING OIL PRESSURE GAGE
TO PIVOT BRAKES
FORWARD RANGE SPOOL
RANGE SELECTOR VALVE
REVERSE RANGE SPOOL
LOCK-OUT SPOOL
PILOT CONTROL VALVE
TO CLUTCH PACKS
HI-LO SHIFT HOUSING
REAR MAIN FRAME SUMP
TRANSMISSION
STEERING BOOSTERS
SUCTION FILTER
CLUTCH OIL PRESSURE GAGE
INPUT PUMP
PRESSURE FILTER
SAFETY FILTER
OIL COOLER
TORQUE CONVERTER
MAIN OIL PRESSURE
LUBRICATING OIL PRESSURE
CONVERTER OUTLET PRESSURE
CONVERTER INLET PRESSURE
RETURN AND SUCTION LINES

81.576

Figure 11-27.—Hydraulic oil flow diagram (hydraulically controlled transmission).

Table 11-2.—Troubleshooting Chart for International Harvester (TD-20 Series B Tractor and Model 250 Series B Loaders) Power Shift Transmission.

Trouble	Possible Causes	Corrective Measures
Main oil pressure gage shows low or high pressures.	Pressure gage malfunction.	Replace gage.
	Plugged suction or pressure filter.	Clean suction filter. Replace pressure filter element.
	Air leakage at suction filter.	Tighten fittings or replace "O" rings.
	Air entry into suction line.	Replace Marmon clamp gasket. Replace "O" rings in system.
	Main regulating valve springs malfunctioning.	Remove and replace with new valve springs.
	Wrong number of washers at main regulating valve springs.	Do not use more than a total of four washers.
	Binding of lube valve, bypass valve or main pressure valve in regulator housing.	Check valves. Install new valve body gasket.
	Charging pump malfunctioning.	Replace pump.
Low oil pressure when in forward or reverse speed.	Contaminated or restricted oil lines.	Clean or replace oil lines.
	Shims or "O" ring leaking at reverse clutch shaft manifold.	Replace with new shims or "O" rings.
	Tachometer drive plug "O" ring leaking.	Replace "O" ring.
	"O" ring at clutch shaft end cover leaking.	Replace "O" ring.
	Oil leakage past cover and case gasket at reverse manifold.	Replace gasket.
	Hook type seal rings on shaft leaking.	Replace seal rings.
	Clutch piston seal ring leaking.	Replace seal ring.
Slow or erratic clutch engagement.	Low oil level.	Add oil to proper level.
	Clogged filters.	Remove and clean suction and safety filters. Replace pressure filter element.
	Faulty hydraulic oil pump.	Replace worn parts or replace pump.

81.577

Table 11-2.—Troubleshooting Chart for International Harvester (TD-20 Series B Tractor and Model 250 Series B Loaders) Power Shift Transmission—continued.

Trouble	Possible Causes	Corrective Measures
Slow or erratic clutch engagement—continued.	Internal oil leaks.	Check for damaged or worn sealing rings in clutch packs.
	External oil leaks.	Check all gaskets, lines and connections.
	Low main oil pressure.	Clean main regulator valve and bore; check spring tension.
	Selector hand lever improperly adjusted.	Adjust as described in service manual.
	Contaminated or restricted oil lines.	Clean or replace oil lines.
	Binding of main pressure valve in regulator housing.	Check valve. Install new valve body gasket.
	Range selector valve wiper seal leaking.	Replace seal.
Noise in transmission.	Bearings worn or broken. Worn drive gear and drum bushings.	Remove and install new parts.
	Foreign material in oil.	Drain, flush and refill with clean oil. Clean suction and safety filters. Replace pressure filter element.
	Gears badly worn.	Install new gears.
	Bevel gear and pinion not in proper mesh.	Adjust to proper clearance.
High oil temperature.	Clogged oil cooler.	Remove and clean.
	Improper tractor operation.	Operate in correct range.
	Improper torque converter operation.	Refer to table 11-1.
	Low or high oil level.	Add or drain to proper level.
	Oil leakage.	Check all gaskets, lines and connections and replace parts as necessary.
	Faulty thermo bypass valve (if equipped).	Discard valve assembly.
	Faulty hydraulic oil pump.	Replace worn parts or replace pump.
	Temperature gage malfunction.	Replace gage or sending unit.
	Air entry into suction line.	Replace Marmon clamp gasket. Replace "O" rings in system.

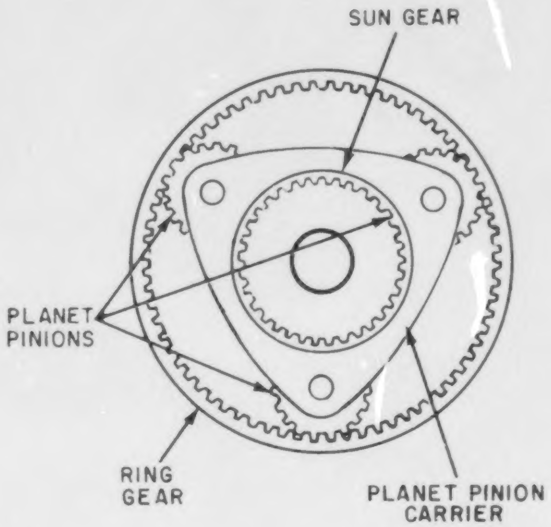
81.577

Planetary Gear Sets

Other types of power shift transmissions use a combination of PLANETARY GEAR SETS to perform the same functions as the transmission just described.

A planetary gear set (fig. 11-28) consists of three members: sun gear, ring gear, and planetary carrier which holds the planetary gears in proper relation with the sun and ring gear. The planetary gears are free to rotate on their own axes while they "walk" around the sun gear or inside the ring gear.

To cause a reduction or increase in torque, six different methods of connecting this gear set to the power train are possible. Another method provides direct drive and neutral can be obtained by allowing all the gears to turn freely. By comparing the chart shown in figure 11-29 to the simple planetary gear arrangements shown in figure 11-30, you can see how this is possible.



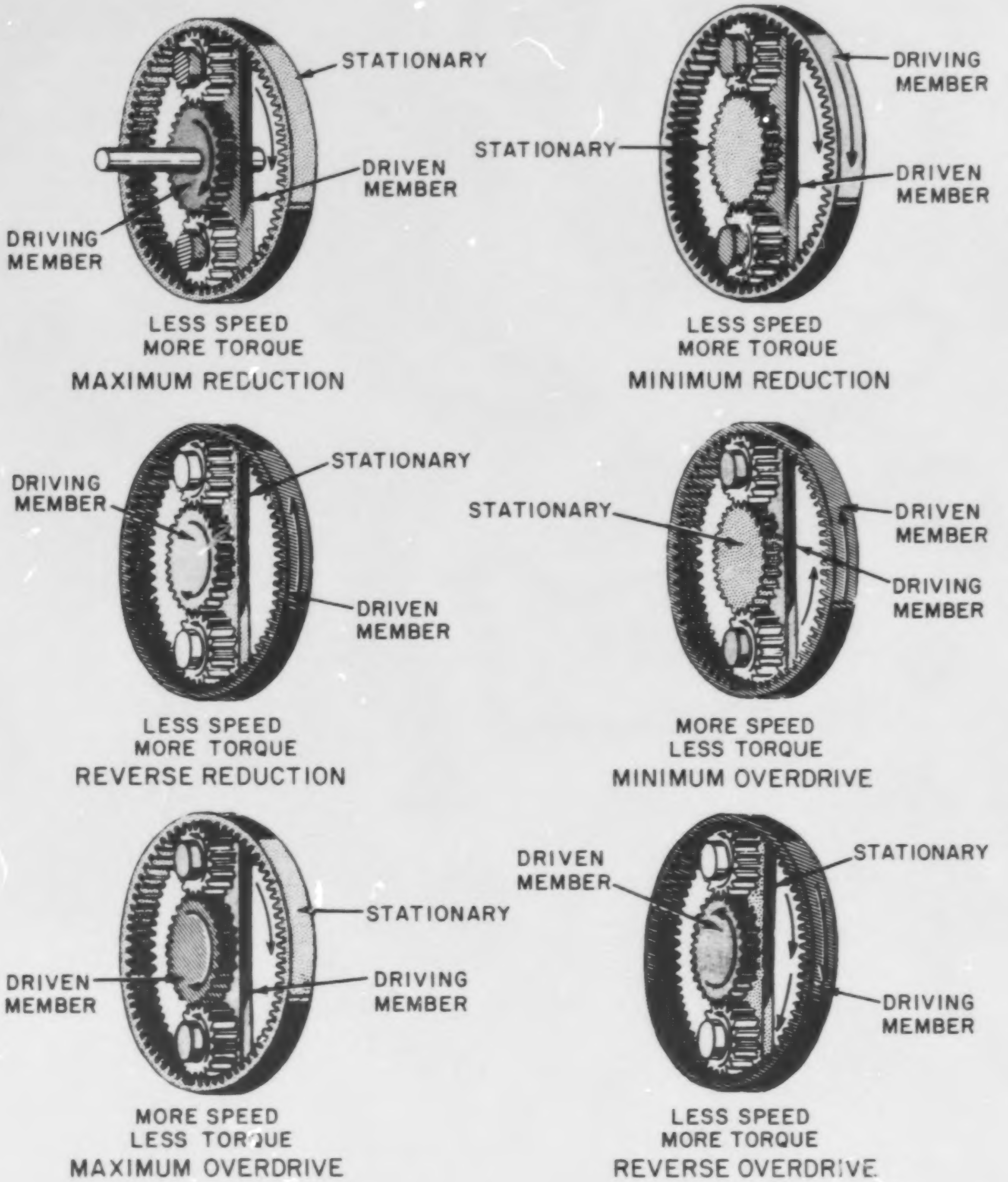
81.578

Figure 11-28.—Planetary gear set.

CASE	STATIONARY MEMBER	DRIVING MEMBER	DRIVEN MEMBER	RESULT
ONE	RING	SUN	CARRIER	MAXIMUM REDUCTION
TWO	SUN	RING	CARRIER	MINIMUM REDUCTION
THREE	CARRIER	SUN	RING	REVERSE REDUCTION
FOUR	SUN	CARRIER	RING	MINIMUM OVERDRIVE
FIVE	RING	CARRIER	SUN	MAXIMUM OVERDRIVE
SIX	CARRIER	RING	SUN	REVERSE OVERDRIVE
SEVEN	NONE (TWO LOCKED TOGETHER)	ANY	ANY	DIRECT DRIVE
EIGHT	NONE	ANY	NONE	NEUTRAL

81.212

Figure 11-29.—Tabular summary of the possible combinations for a planetary gear set.


STATIONARY
DRIVEN MEMBER
DRIVING MEMBER
DRIVING MEMBER
STATIONARY
DRIVEN MEMBER
STATIONARY
DRIVING MEMBER
DRIVEN MEMBER
STATIONARY
DRIVEN MEMBER
DRIVING MEMBER
STATIONARY
DRIVEN MEMBER
DRIVING MEMBER
DRIVEN MEMBER
STATIONARY
DRIVING MEMBER

LESS SPEED
MORE TORQUE
MAXIMUM REDUCTION

LESS SPEED
MORE TORQUE
MINIMUM REDUCTION

LESS SPEED
MORE TORQUE
REVERSE REDUCTION

MORE SPEED
LESS TORQUE
MINIMUM OVERDRIVE

MORE SPEED
LESS TORQUE
MAXIMUM OVERDRIVE

LESS SPEED
MORE TORQUE
REVERSE OVERDRIVE

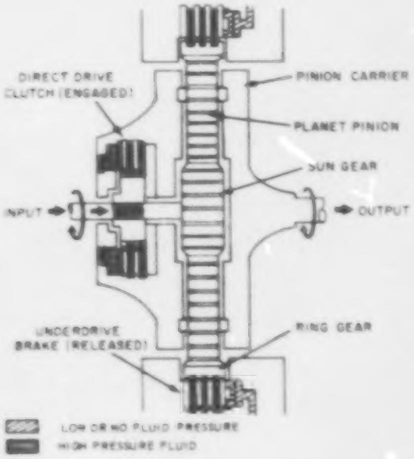
2.210

Figure 11-30.–Planetary gear arrangements that will provide an increase or decrease in speed.

Notice the direction of rotation as power is applied to the various members and others are held stationary. In actual application, planetary gear sets are used as single or multiple units, depending on the number of speed (gear) ranges desired.

On wheel or crawler mounted equipment, power for turning the wheels or drive sprockets may flow through a planetary gear arrangement that provides maximum reduction. (See fig. 11-30.) The sun gear forces the planet gears to revolve inside the stationary ring gear and move the planet carrier in the same direction of rotation as the sun gear. The planet carrier is connected to the hub on which the wheel or sprocket is mounted, causing it to rotate with the planet carrier. This arrangement produces the maximum torque and speed reduction obtainable from a planetary gear set.

Figure 11-31 illustrates the simplest application of planetary gears in a transmission. With the arrangement shown, two forward speeds and neutral are possible. High gear or direct drive is shown. The clutch is holding the planet carrier to the input shaft causing the carrier and sun gear to rotate as a single unit. With the clutch released, all gears are free to rotate and no power is transmitted to the output shaft. In neutral, the planetary carrier remains stationary while the pinion gears rotate on their axes and turn the ring gear. Should the brake be engaged on the ring gear, the sun gear causes the planetary gears to walk around the inside of the ring gear and force the planet carrier to rotate in the same direction as the sun gear, but at a slower speed (low gear). To provide additional speed ranges or a reverse, other planetary gear sets must be added to this transmission. A power shift transmission with planetary gears can be made to operate automatically by changing the method of controlling speed changes.



81.579

Figure 11-31.—Simple planetary gear application.

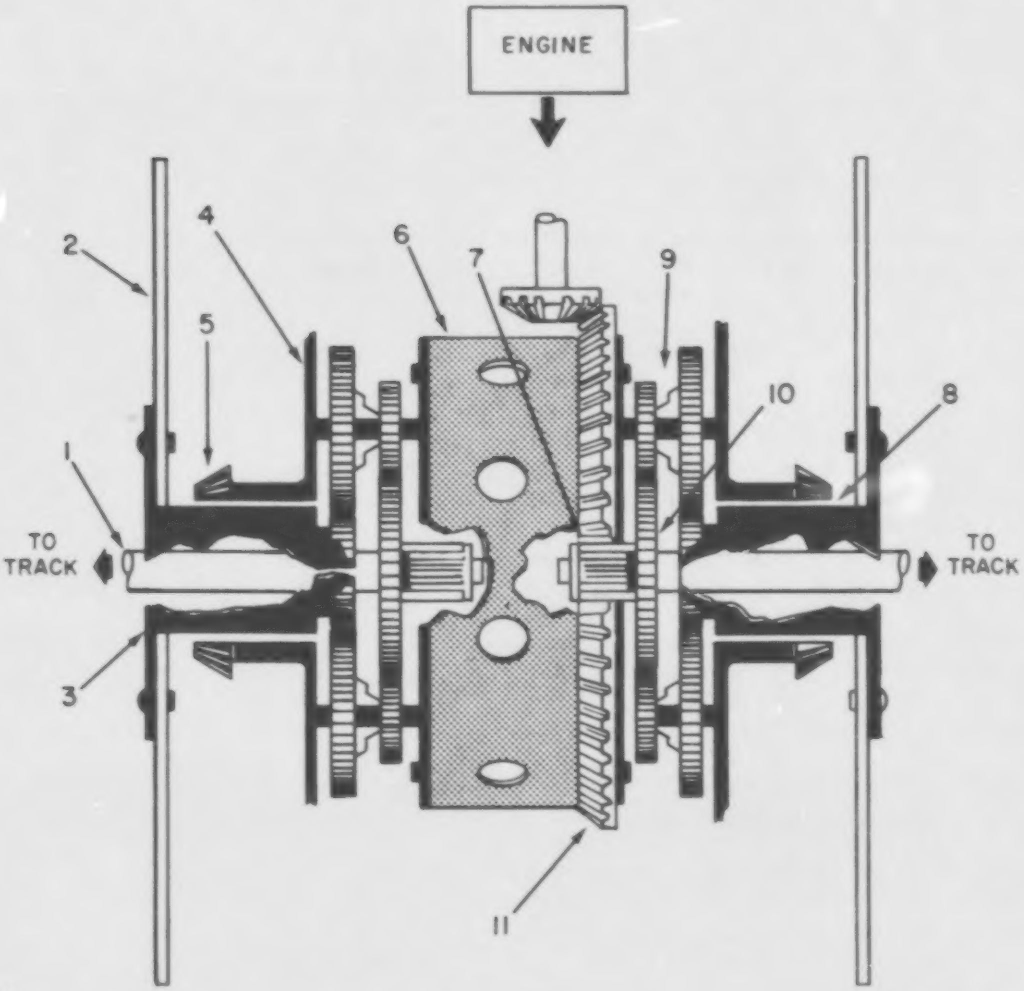
AUTOMATIC TRANSMISSIONS

A system must be provided within an automatic transmission to shift automatically from one gear range to another as the speed and power requirements of the vehicle vary. In modern automatic transmissions, automatic shifting is accomplished through a system of hydraulically operated clutches, bands, servos, governors, and valves. The pump provides a means of developing hydraulic pressure. This hydraulic pressure is directed by the various valves to the hydraulic clutches and servos that control the planetary gears. The transmission is a mechanical and hydraulic balance controlled by the governor pressure, throttle valve pressure, or spring pressure. The manual control lever selects the range of transmission operation.

The procedures for the maintenance and repair of automatic transmissions vary considerably among makes and models of transmissions. For this reason no procedures for maintenance and repair are presented here. It is suggested that, when repairs are to be performed, you follow the procedures outlined in the manufacturer's maintenance manual for the transmission being repaired. Adjustments to an automatic transmission must be made accurately if the unit is to operate properly.

PLANETARY STEERING

International Harvester crawler tractors are steered by a system that combines planetary gears and pivot brakes. The planetary steering system (fig. 11-32) differs from the one previously described in that the planetary pinion gears are two gears of different size machined as one piece. Two sun gears are also included. One



1. **Sprocket Drive Shaft**
2. **Steering Brake Disk**
3. **Steering Brake Hub and Sun Gear**
4. **Planetary Carrier**
5. **Planetary Carrier Bearing**
6. **Bevel Gear Carrier**
7. **Sprocket Drive Shaft Support Bushings**
8. **Steering Brake Support Bushings**
9. **Planetary Gears**
10. **Sprocket Drive Shaft Sun Gear**
11. **Bevel Gear**

81.580

Figure 11-32.—Planetary steering systems.

sun gear is splined to the sprocket pinion shaft and the other is machined on the steering brake hub. The sun gear on the brake hub performs the same function as the ring gear in conventional planetary systems. Bushings are used to isolate the sprocket drive shafts and the steering brake hubs from the bevel gear carrier and planetary carrier. The complete unit is supported by large roller bearings on the ends of the planetary carrier. Lubrication is provided from the oil sump located below the assembly.

When a crawler tractor travels straight ahead, its steering brakes are held in the applied position by heavy coil springs. Braking prevents the steering brake hub and sun gear from rotating, and forces the large planetary pinion gears to "walk" around this sun gear. Then, power is transmitted to the sun gear on the sprocket drive shaft from the smaller planetary pinion gears.

When making a gradual turn, the tractor operator moves one of the steering levers back far enough to release the steering brake on one end of the planetary system. When the brake is released, the planetary pinion gears stop "walking" around the sun gear on the steering brake hub. This hub then rotates with the planetary carrier, and no power is transmitted to the sprocket drive shaft.

Occasionally, an adjustment of the steering brake is required to prevent slippage when it is engaged. To reach the adjustment points, you must remove the pipe plugs that are located below the fenders on the sides of the tractor frame. Consult the manufacturer's manual for proper adjustment procedures.

PIVOT BRAKES

The pivot brakes on these tractors are of the multiple disk type. They are operated by a foot pedal or individually by pulling the steering levers fully to the rear. The middle disks (splined to the sprocket drive shaft) have laminated linings. The intermediate disks (held in position by studs) are smooth steel disks. An actuating disk assembly is located in the center of the disks and is connected to the operating linkage. This assembly consists of two steel plates with steel balls located between them. Ramps are machined on the plates and when the brakes are applied, the steel balls move up the ramps and force the plates apart. Movement of the plates causes the disks to be squeezed together and to stop rotation of the sprocket drive shaft. When these brakes are fully applied, the tracks will stop. The steering levers are linked to the brakes independently to actuate them for sharp turns.

Adjustment of the pivot brakes are sometimes required to provide adequate braking with the steering lever or foot pedal. An adjustment is needed when the steering levers can be pulled against the seat with the engine running, or the foot pedal bottoms. Always follow the procedures in the maintenance manual when making this adjustment. The adjustment is made in the linkage located under the operator's seat.

TRACKS AND TRACK FRAMES

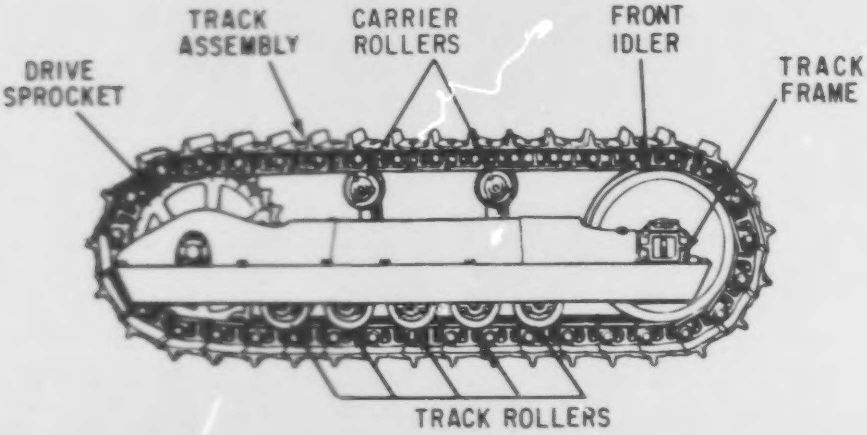
The undercarriage of crawler mounted equipment contains two major components: TRACK ASSEMBLY AND TRACK FRAME. This undercarriage (fig. 11-33) is provided on equipment that must have positive traction to operate efficiently.

TRACK ASSEMBLY

The track assembly consists of a continuous chain surrounding the track frame and drive sprocket. The links of the chain provide a flat surface for the track rollers to pass over as they support the equipment. Track shoes are bolted to the outside of the chain's links and distribute the weight of the equipment over a large surface area.

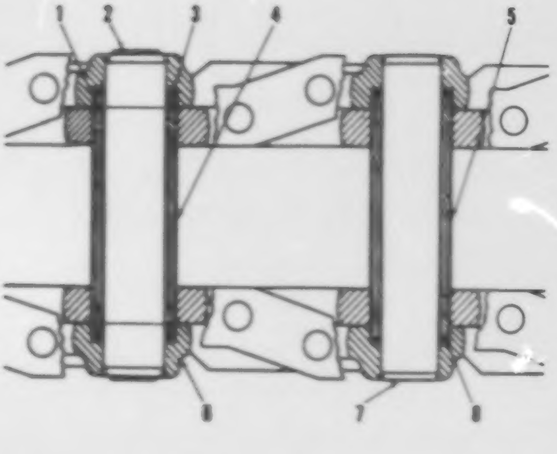
Track Chain

Figure 11-34 illustrates a section of track chain cut away to show the internal arrangement of the pins and bushings. As the tractor operates, the drive sprocket teeth contact the track pin bushings and propel the tractor along the track assembly.



81.417

Figure 11-33.—Side view of crawler tractor chassis.



1. Spacer
2. Master Pin
3. Coned-Disk Seal Washers
4. Master Bushing
5. Track Bushing
6. Link
7. Track Pin
8. Coned-Disk Seal Washers

81.4[illegible]9

Figure 11-34.—Track chain cutaway.

The pins and bushings wear much faster than other parts of the track because of their constant pivoting as the track rotates around the track frame. This pivoting results in internal wear of both the pin and bushing. As the pins and bushings wear, the track lengthens. When it does, the track should be adjusted to remove excessive slack.

Bushings that show lots of wear on the outside are good indicators of inner wear that is also nearing the maximum allowed by the manufacturer, if the track is to be rebuilt. To determine whether the track should be removed for rebuilding or replacement, measure the outside of the bushings and track "pitch" (length of the track). Use an outside caliper and ruler as shown in figure 11-35. Measure the outside of the bushing where it shows the most wear and compare it to the manufacturer's specifications.

Measure track pitch with a ruler or tape measure after tightening the track to remove any slack as shown in figure 11-36.

Should the bushing wear or track length be excessive, remove the track for rebuilding unless facilities and time do not permit[illegible]ilding a track will nearly double the usefu[illegible] of the pins and bushings.

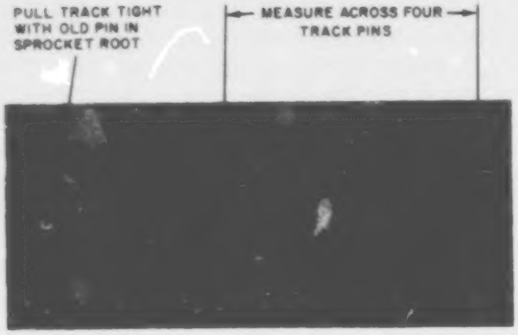
Track Shoes

The most common track shoe is the grouser shoe shown in figure 11-37. This shoe is standard on all crawler tractors with bulldozer blade attachments.

The extreme service track shoe shown in figure 11-38 is found on crawler tractors that operate primarily in rocky locations, such as rock quarries and coral beaches. Notice that the

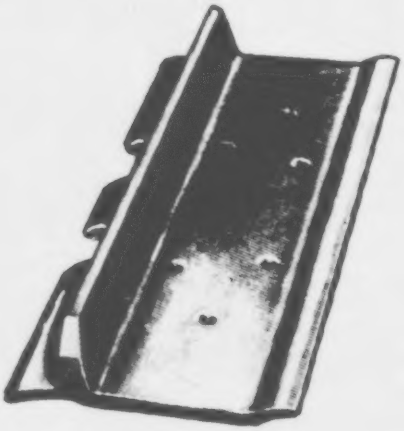
81.423

Figure 11-35.—Bushing wear measurement.


PULL TRACK TIGHT WITH OLD PIN IN SPROCKET ROOT
MEASURE ACROSS FOUR TRACK PINS

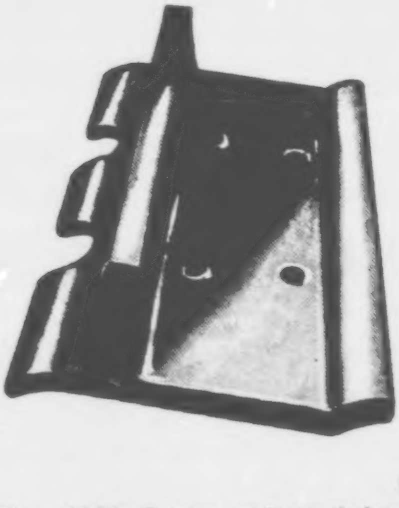
81.424

Figure 11-36.—Measure across 4 links for pin and internal bushing wear.



81.405

Figure 11-37.—Standard grouser shoe.



81.406

Figure 11-38.—Extreme service track shoe

grouser, or raised portion of the shoe, is heavier than the one on the standard grouser shoe shown in figure 11-37. The grouser absorbs most of the wear and its condition can indicate that the track needs replacement or overhaul.

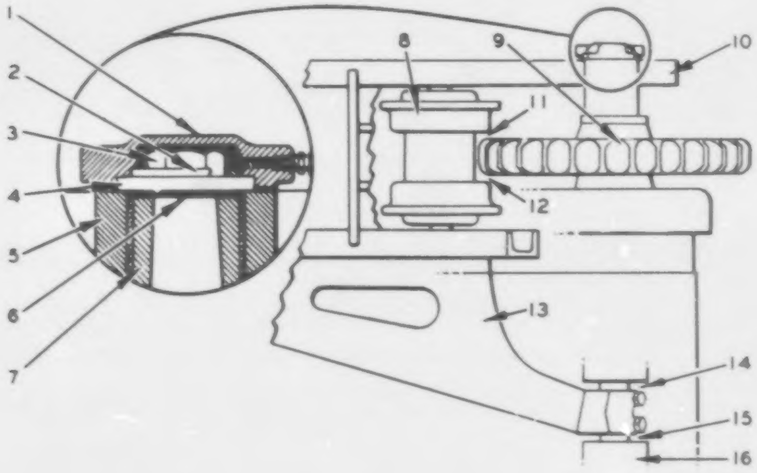
Another shoe common to track-mounted front end loaders is the multipurpose shoe. This shoe (not illustrated) has three grousers that extend a short distance above the shoe and are equally spaced across its face. The multi-purpose shoe allows more manuverability with less wear on the track and track frame components.

TRACK FRAME

The track frame, as the name implies, serves as a framework and support for the track assembly, rollers, front idler, recoil spring, and adjusting mechanism. Alinement of the track frame on International Harvester tractors is maintained by shims where it attaches to the pivot shaft at the rear and near the center of the track frame where it is mounted against the main frame guide brackets. A diagonal brace and shims are used to aline track frames on the Caterpillar tractor (fig. 11-39).

Track Frame Rollers

Two types of track frame rollers are used on tracked equipment; those located on the lower portion of the track frame which support the weight of the tractor, and those above the track frame, which support the track as it passes over the track frame assembly.



1. Cap
2. Lock Ring
3. Nut
4. Washer Assembly
5. Outer Bearing Assembly
6. Shims
7. Bearing Holder
8. Rear Track Roller
9. Drive Sprocket
10. Track Roller Frame
11. Clearance
12. Clearance
13. Diagonal Brace
14. Clearance
15. Clearance
16. Steering Clutch Case

81.435

Figure 11-39.—Alining track roller frame with sprocket.

The carrier rollers (fig. 11-40) are mounted on brackets which extend above the track frame. Two of these rollers are on each side of the tractor. They are of the single flange type. The flange extends upward between the links of the track chain and keeps the chain in alinement between the drive sprocket and the front idler.

The track rollers (fig. 11-41) support the tractor's weight and insure that the track chain is in alinement with the track frame as it passes under the rollers. Track rollers, both single and double flanged, are installed alternately. In the normal arrangement, a double flanged roller is directly in front of the drive sprocket, followed by a single flanged roller. The rollers alternate forward to the front idler.

Front Idler

The front idler (fig. 11-41) serves as a guiding support for the track chain. The idler is spring loaded and mounted on slides or guides that allow it to move back and forth inside the track frame as the tractor passes over uneven ground. The spring loading effect causes the idler to maintain the desired tension regardless of operating conditions.

Recoil Spring

The recoil spring is a large coil spring placed in the track frame in a way that enables the spring to absorb shock from the front idler. The spring is compressed before installation and held in place by stops or spacers. The track adjusting mechanism, by pressing against the spring stop, maintains the desired tension on the track assembly by holding the idler and yoke in the forward position. The recoil spring's operation depends on the amount of tension on the track.

Adjusting Mechanism

The adjusting mechanism must be extended enough to remove slack between the front idler and spring. The adjustment is made either manually (fig. 11-42) or hydraulically (fig. 11-43). All older model tractors have manual adjustments whereas the newer tractors are

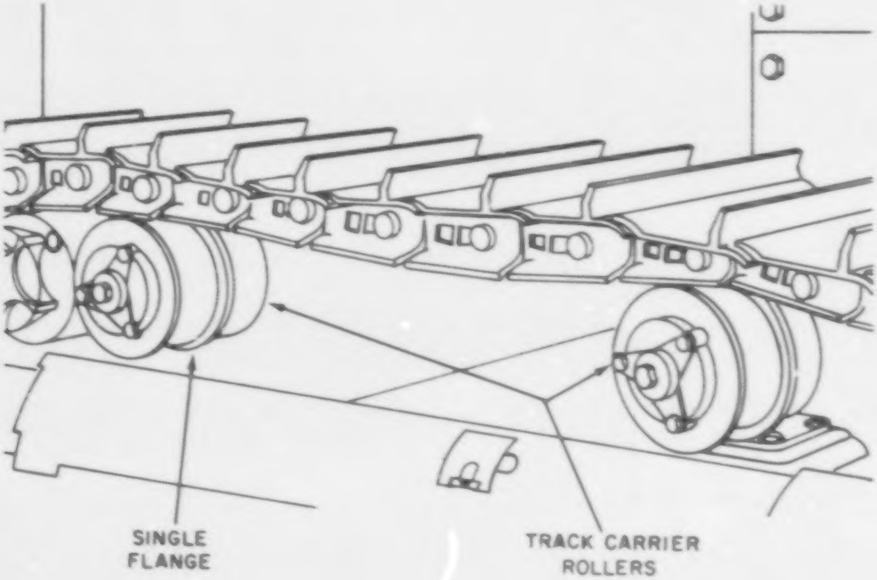


Figure 11-40.--Track carrier rollers.

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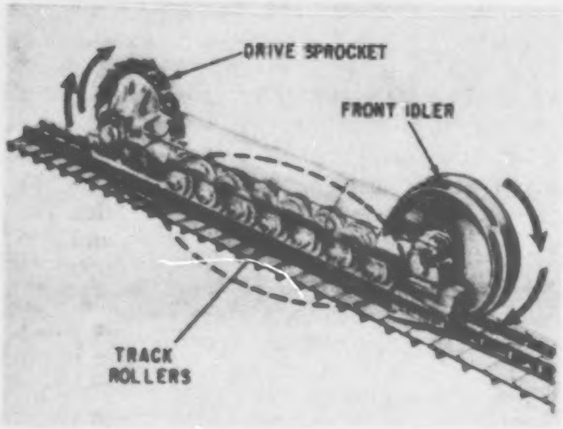
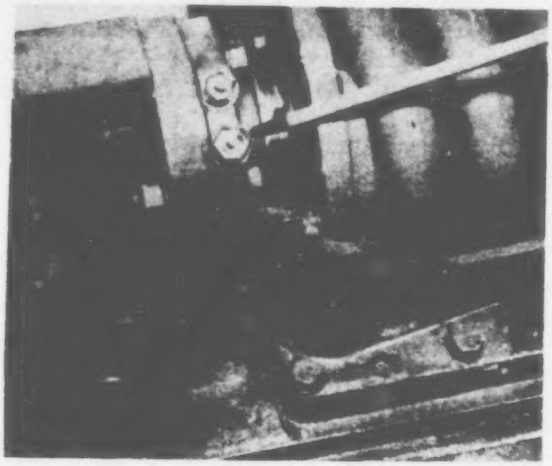


81.404
Figure 11-41.—Track rollers in position in track frame.

81.416
Figure 11-42.—Manual track adjustment.

adjusted hydraulically with a grease gun. Grease is pumped into the yoke cylinder and extends it until enough tension is placed on the recoil spring to remove the slack from the track. Tension is relieved by loosening the vent screw located next to the adjustment fitting. DO NOT LUBRICATE THIS FITTING WHEN PERFORMING MAINTENANCE ON THE TRACTOR.



81.415
Figure 11-43.—Caterpillar hydraulic track adjuster.

Track Guiding Guards

Accumulations of rock packed in the track cause tracks to tighten, which results in additional wear and stress on the track components. The use of track guiding guards minimize these sources of possible depreciation. Another function of track guiding guards, that of keeping the track in proper alinement, is sometimes considered secondary, but actually, it is the most important function. Guiding guards should be repaired when first found to be damaged, since a damaged guard is usually worthless as far as protection or assistance in maintaining track alinement is concerned. When installing new tracks on a machine, check the condition of the track guiding guards. These guards should be reconditioned to proper thickness so they will guide the track squarely into alinement with the track rollers.

The front guiding guards receive the track from the idler and hold it in line for the first roller. The front roller then can be utilized fully for its intended purpose, that of carrying its share of the tractor load without having to climb the sides of the improperly alined track.

The rear guiding guards hold the track in correct alinement with the driving sprocket, permitting a smooth even flow of power from the sprocket to the track. With proper alinement, the gouging of link sides and sprocket teeth is eliminated.

The center guiding guards or track roller guards (fig. 11-44) are available as attachments, and are a continuation of the "hold the line" safeguard so important to extending track life. These center guards keep the track in line between the rollers when operating in rocky, uneven, or steep sloped terrain, thereby reducing wear on the roller flanges and track links.

MAINTENANCE OF TRACK AND TRACK FRAME ASSEMBLIES

Some maintenance of track and track frames is performed at the jobsite by the field maintenance crew. It consists of track adjustment, lubrication as necessary, and inspection of the track and track frame components to determine whether or not the tractor should be taken to the shop for repairs.

TRACK ADJUSTMENT

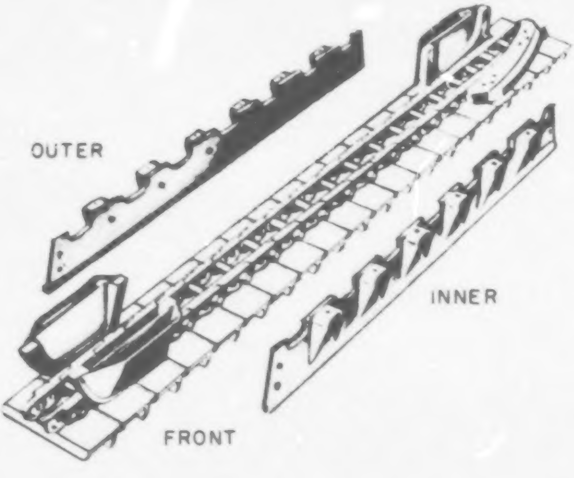
In one method for determining proper track tension, a straightedge is placed over the front carrier roller and idler with all slack removed from the rest of the track. The tension is proper when the measured distance is as indicated by figure 11-45. In another method of adjustment all slack is removed from the track and the adjustment is then backed off until the front idler moves back 1/2 inch. Always check the maintenance or operator's manual for the procedure to follow when adjusting tracks.

If the tracks are adjusted too tightly, there will be too much friction between the pins and bushings when the track links swivel as they travel around the sprocket and front idler. This friction causes the pins, bushings, links, sprocket, and idler to wear rapidly. Friction in a tight track also robs the tractor of needed horsepower.

Tracks that are too loose fail to stay alined and tend to come off when the tractor is turned. As a result, the idler flanges, roller flanges, and the sides of the sprocket teeth wear down. A loose track will whip at high tractor ground speed, damaging the carrier rollers and their supports. If loose enough, the drive sprocket will jump teeth (slide over the track bushings) when the tractor moves in reverse. Should this happen, the sprocket and bushings will wear rapidly.

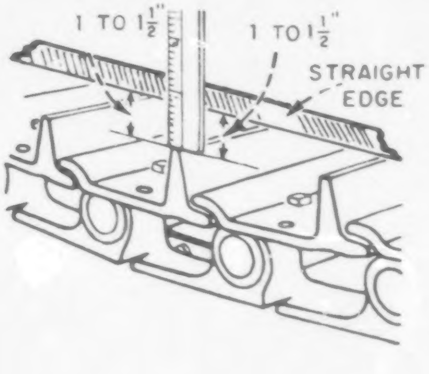
LUBRICATION

The track pins and bushings are hardened and require no lubrication. Many rollers and



81.429

Figure 11-44.—Track guiding guards.



115.456

Figure 11-45.—Checking track adjustment.

idlers are equipped with lifetime seals which are filled during assembly and need not be lubricated. However, track rollers, carrier rollers, and idlers equipped with grease fittings must be lubricated on a scheduled basis. These fittings should be cleaned prior to lubricating to prevent forcing dirt and grime into the bearings. Use a low pressure lubrication pump on these fittings and pump only until you start feeling resistance on the lever of the pump.

INSPECTION

When performing routine maintenance, inspect the complete track and undercarriage for signs of abnormal wear, leaking rollers or idlers, and misalined, loose, or missing parts. Should you find loose track shoes, it is good practice to check the torque on all the shoe bolts and tighten them with a torque wrench as prescribed by the manufacturer.

If the track appears to be out of alinement, report this to your supervisor who will determine whether or not corrective action is required. Leaking roller or idler seals should be replaced at scheduled maintenance periods or as soon as shop workload permits.

SHOP REPAIRS

Repairs made to tracks and track frames in the maintenance shop are usually limited to replacing roller or idler seals and bearings or repairing a hydraulic track adjuster. On occasion, you may find a roller or track that is badly worn and requires replacement. Never replace components of the track or track frame without consulting the wear limitation charts in the manufacturer's service manual.

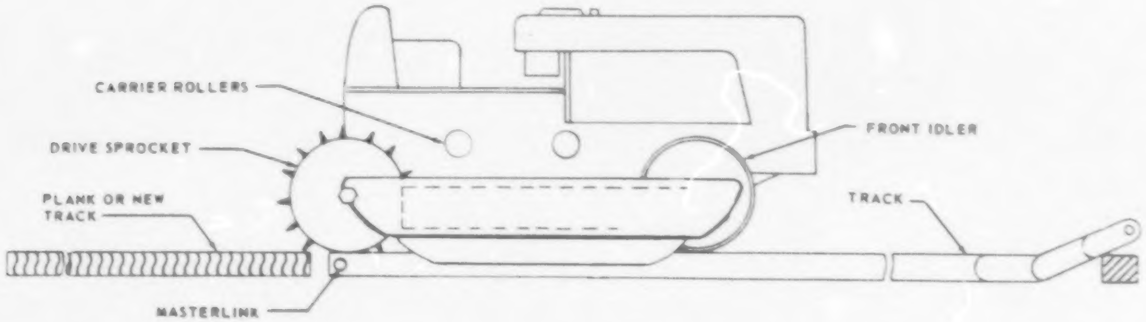
Buildup of the component wearing surfaces, except at established overhaul facilities, is not recommended unless the piece of equipment is essential to the mission of the unit. In this case, a Steelworker will rebuild the components and a Machinery Repairman, assigned to the maintenance shop, will do the machine work.

Crawler tractor rollers can be removed individually by releasing track tension and placing a suitable hydraulic jack between the track and track frame. The jack enables you to move the track clear of the roller flanges. To remove the front idler and the adjusting mechanism for repairs, you must remove the track.

Track Removal

To remove the track, (fig. 11-46) follow the steps below:

1. Release the track tension by manually backing off the track adjustment, or loosening the vent screw on the hydraulic track adjuster.



81.317

Figure 11-46.—Removing tracks.

2. Remove the master pin. The master pin can be identified by a locking device or hole drilled in its end that distinguishes it from the other pins in the chain. Move the tractor backward slowly to bring the master pin just below the level of the drawbar or on some models, forward, and place a block under the grouser on a shoe that allows the master pin to be centered on front idler. If the pin contains a locking device, remove the locking device, and drive the pin out with a sledge and a soft metal drift pin. Should the pin be drilled, a portable press must be used to remove the pin. Do not lose the bushings, which may drop out with the pin.

3. Remove the track from the carrier rollers and idler by slowly moving the tractor forward or backward away from the loose ends. Make sure no one is in the way of the tractor or loose end of the track when it falls off the sprocket or front idler.

4. Move the tractor off the track onto a plank. The plank should be about the same thickness as the track, narrow enough to fit between the track frame and shields, and long enough so that the entire tractor can rest on the plank.

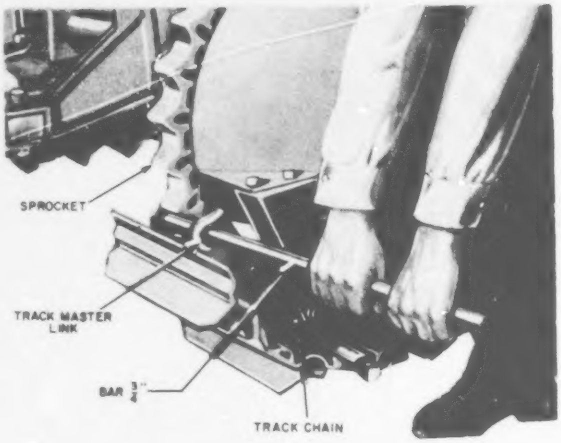
After removing the tracks, always see that the tractor is securely blocked while repairs are being made.

Anytime a track is removed, thoroughly inspect the components of the track frame for excessive wear or misalinement. As mentioned earlier, repairs in the maintenance shop are normally limited to replacement of seals, bearings, or bushings contained in the rollers or idler and occasionally replacing seals in a hydraulic track adjuster.

Procedures for the removal, disassembly, and replacement vary by model and manufacturer. Always consult the manufacturer's service manual before making repairs.

Replacing Tracks

To replace the tracks, back the tractor on the new tracks so that the drive sprocket meshes properly with the track rail. Continue backing until the tractor is just ahead of the rear end of the track. Then place a bar in the track as shown in figure 11-47, and help the track climb over the sprocket, carrier rollers, and idler as the tractor is driven forward. When the track comes together, you can install the master pin and lock. Once the track is back together, adjust the track tension using the manufacturer's recommended procedures.



81.318

Figure 11-47.—Pulling track over sprocket.

MAINTENANCE TIPS AND INDICATORS FOR TRACTORS

1. When operating in mud or water, lubricate the rollers twice daily (older tractors).
2. Be sure both tracks are adjusted equally.
3. Never use a pressure type lubricator to lubricate the track rollers and idlers.
4. Never apply lubricants to the tracks.
5. Check to see that all the carrier rollers and track rollers are free to turn.
6. If the tractor pulls slightly to one side during operation, this may indicate the tracks are not equally adjusted.
7. Flat spots on the track rollers and carrier rollers will indicate the rollers are not turning freely.
8. Wear on the idler flange indicates a misalined idler.

WIRE ROPE

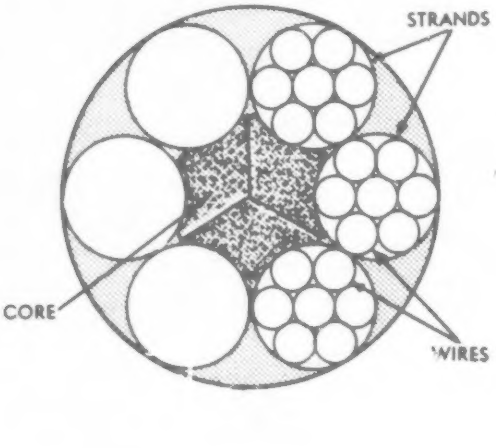
As a Construction Mechanic, you will sometimes be required to replace wire rope on equipment and attachments. Wire rope is extensively used with cranes and winches on wheeled and track-mounted equipment.

COMPOSITION AND CHARACTERISTICS

Wire rope consists of three parts: wires, strands, and core (fig. 11-48). In the manufacture of rope, a number of wires are laid together to form the STRAND. Then a number of strands are laid together, usually around a CORE, to form the rope.

The basic unit of wire rope construction is the individual wire, which may be made of steel, iron, or other metal, in various sizes. In making a rope, the number of wires to a strand will vary, depending on the purpose for which the rope is intended. Wire rope is designated by the number of strands per rope and the number of wires per strand. Thus, a 1/2" 6 x 19 rope will have 6 strands with 19 wires per strand, but will have the same outside diameter as a 1/2" 6 x 37 wire rope, which will have 6 strands with 37 wires of much smaller size per strand.

Wire rope made up of a large number of small wires is flexible, but the small wires are easily broken so the wire rope is not resistant to external abrasion. Wire rope made up of a smaller number of larger wires is more resistant to external abrasion but is less flexible.



29.172

Figure 11-48.—Parts of wire rope.

The CORE—the element around which the strands are laid to form the rope—may be a hard fiber (such as manila, hemp, plastic, paper, asbestos, or sisal), a wire strand, or an independent wire rope. Each type of core serves the same basic purpose, that of affording support to the strands laid around it.

A FIBER CORE offers the advantage of increased flexibility. In addition, it serves as a cushion to reduce the effects of sudden strain and acts as a reservoir for the oil necessary for lubrication of the wires and strands to reduce friction between them. Wire rope having a fiber core is used in places where flexibility on the part of the rope is important.

A WIRE STRAND CORE not only provides more resistance to heat than a fiber core, but also adds about 15 percent to the strength of the rope. On the other hand, the wire strand makes the rope less flexible than when a fiber core is used.

AN INDEPENDENT WIRE ROPE CORE is a separate wire rope over which the main strands of the rope are laid. It usually consists of six 7-wire strands laid around either a fiber core or a wire strand core. This type of core gives the rope additional strength, provides support against crushing, and supplies maximum resistance to heat.

Wire rope may be fabricated by either of two methods. If the strands or wires are shaped to conform to the curvature of the finished rope prior to laying up, the rope is termed PREFORMED. If they are not shaped before fabrication, the rope is termed NONPREFORMED. Preformed wire rope is more flexible than nonpreformed wire rope, and when it is cut, the wires and strands tend to remain in place. With nonpreformed wire rope, the twisting process produces a stress in the wires, and when it is cut or broken the stress causes the strands to unlay. In nonpreformed wire, unlaying is rapid and almost instantaneous, and could cause serious injury to someone not familiar with it.

Wire rope is manufactured in a number of different GRADES, three of which are: mild plow steel, plow steel, and improved plow steel.

MILD PLOW STEEL rope is tough and pliable. It can stand up under repeated strain and stress, and has a strength of from 200,000 to 220,000 pounds per square inch (psi).

PLOW STEEL wire rope is unusually tough and strong. This steel has a tensile strength (resistance to lengthwise stress) of 220,000 to 240,000 psi.

IMPROVED PLOW STEEL rope is one of the best grades of rope available, and most—if not all—of the wire rope used in your work will be made of this material. It is stronger, tougher, and more resistant to wear than either plow steel or mild plow steel. Each square inch of improved plow steel can stand a strain of 240,000 to 260,000 pounds.

The term LAY refers to the direction of the twist of the wires in a strand and the strands in the rope. In some instances both the wires in the strand and the strands in the rope are laid in the same direction, and other instances in the opposite direction, depending on the intended use of the rope.

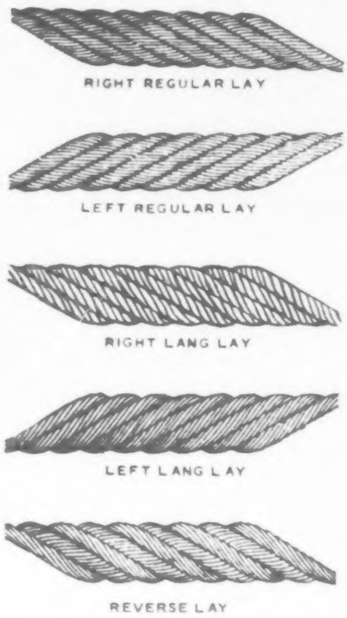
Five different lays of wire rope currently in use are illustrated in figure 11-49. The following explanations will help you recognize and identify each of the five types shown.

RIGHT REGULAR LAY: In this type, the wires in the strands are laid to the left, while the strands in the rope are laid to the right.

LEFT REGULAR LAY: In this case, the wires are laid up to the right to make the strands, then the strands are laid up to the left to form the rope. (In this lay, each step of fabrication is exactly opposite from the right regular lay.)

RIGHT LANG LAY: Here the wires in the strands and the strands in the rope are both laid up to the right.

LEFT LANG LAY: With this type, the wires in the strands and the strands in the rope are also laid in the same direction, but in this instance the lay is to the left (rather than to the right lang lay).



29.173

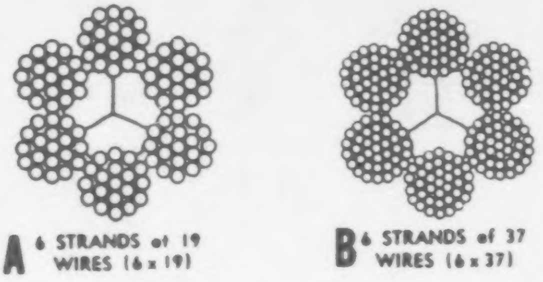
Figure 11-49.—Wire rope lays.

REVERSE LAY: The wires in one strand are laid up to the right, the wires in the adjacent strand are laid up to the left; the wires in the next strand are to the right; and so forth, with alternate directions from one strand to the other. Then all strands are laid to the right.

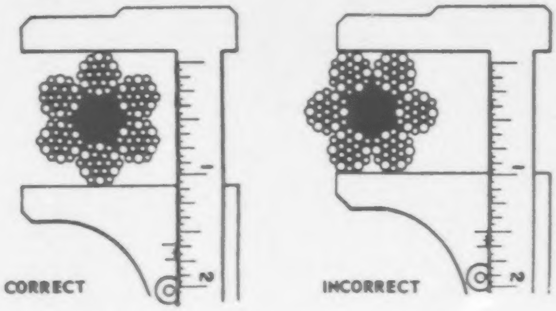
The main TYPES OF WIRE ROPE used by the Navy consist of 6, 7, 12, 19, 24, or 37 wires in each strand. Usually, the rope has 6 strands laid aroung a fiber or steel center.

Two common types of wire rope, 6 x 19 and 6 x 37 rope, are illustrated in figure 11-50. The 6 x 19 type having 6 strands with 19 wires in each strand, is commonly used for rough hoisting and skidding work where abrasion is likely to occur. The 6 x 37 wire rope, having 6 strands with 37 wires in each strand, is the most flexible of the standard 6-strand ropes.

Wire rope is designated as to SIZE by its diameter in inches. The true diameter of a wire


A 6 STRANDS of 19 WIRES (6 x 19)
B 6 STRANDS of 37 WIRES (6 x 37)

29.173
Figure 11-50.–(A) 6 x 19 wire rope; (B) 6 x 37 wire rope.



29.173
Figure 11-51.–Correct and incorrect methods of measuring wire rope.

rope is considered as being the diameter of the circle which will just enclose all of its strands. The correct, as well as incorrect, method of measuring wire rope is illustrated in figure 11-51. Note, in particular, that the RIGHT WAY is to measure from the top of one strand to the top of the strand directly opposite it. The wrong way, as you will note, is to measure across two strands side by side.

Use calipers to take the measurement; if they are not available, an adjustable wrench will do.

To insure an accurate measurement of the diameter of a wire rope, always measure the rope at three places, at least 5 feet apart. Use the average of the three measurements as the diameter of the rope.

The term SAFE WORKING LOAD (SWL), as used in reference to wire rope, means the load that can be applied and still obtain most efficient service and also prolong the life of the rope. There are several rules of thumb which may be used to compute strength of wire rope. The one recommended by the Naval Facilities Engineering Command (NAVFAC) is:

$$\text{SWL (in tons)} = D^2 \times 4,$$

where D represents the diameter of the rope in inches. For example, the SWL of a 2-inch rope

equals $(2)^2 \times 4$ or 16 tons.

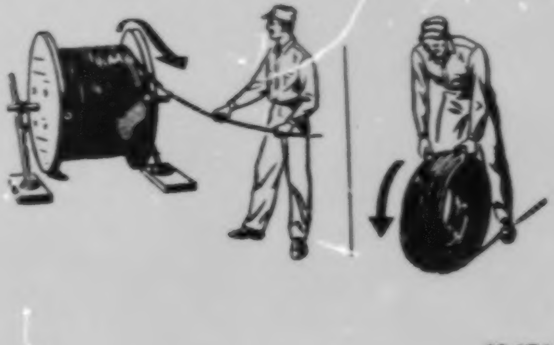
Remember that this is ONLY A RULE OF THUMB. In computing the SWL of old rope, worn rope, or rope which is otherwise in poor condition, you could reduce the SWL as much as 50 percent, depending on the condition of the rope.

Some of the common causes of WIRE ROPE FAILURE are:

1. Using incorrect size, construction, or grade.
2. Dragging over obstacles.
3. Improper lubrication.
4. Operating over sheaves and drums of inadequate size.
5. Overriding or cross-winding on drums.
6. Operating over sheaves and drums with improperly fitted grooves or broken flanges.
7. Jumping sheaves.
8. Subjecting to acid fumes.
9. Improperly attached fitting.
10. Allowing grit to penetrate between the strands, promoting internal wear.
11. Subjecting to severe or continuing overload.

HANDLING AND CARE

To render safe, dependable service over a maximum period of time, wire rope must be given the care and upkeep necessary to maintain it in good condition.

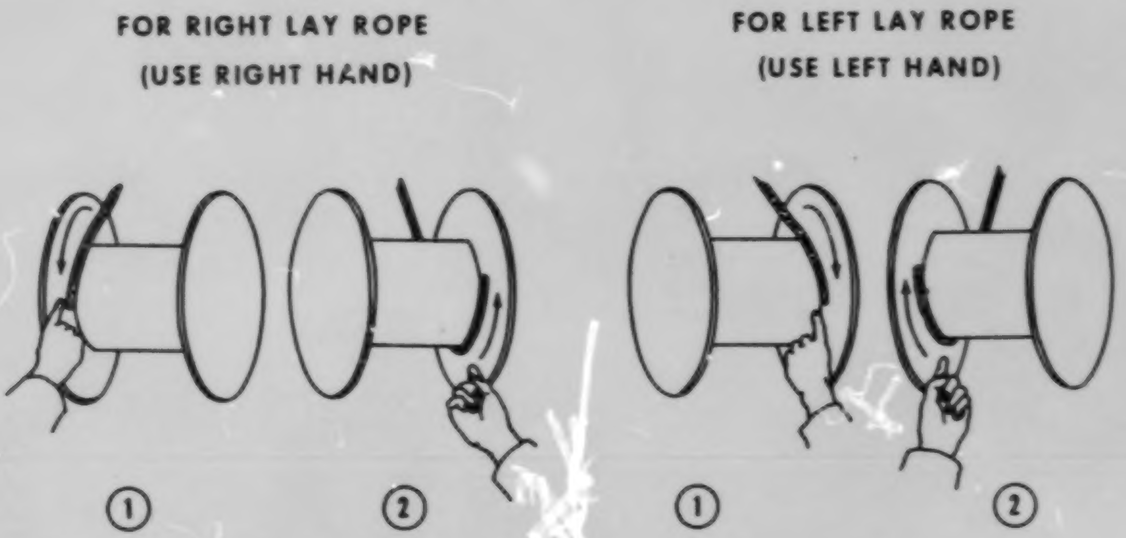


29.174

Figure 11-52.—(Left) Unreeling wire rope. (Right) Uncoiling wire rope.

Wire rope has a strong tendency to kink during UNCOILING or unreeling, especially if it has been in service for a long time. Keep in mind that a kink can cause a weak spot in the rope, which will wear out quicker than the rest of the rope.

A good method for unreeling wire rope is to run a pipe or rod through the center and mount the reel on drum jacks or other supports so that the reel is off the ground. (See fig. 11-52.) In this way, the reel will turn as the rope is unwound, and the rotation of the reel will help keep the rope straight. During unreeling, pull the rope straight forward, as shown in figure 11-52, and try to avoid hurrying the operation. As a



FOR RIGHT LAY ROPE (USE RIGHT HAND)

① **FOR OVERWIND ON DRUM:**

The palm is down, facing the drum.
The index finger points at on-winding rope.
The index finger must be closest to the left-side flange.
The wind of the rope must be from left to right along the drum.

② **FOR UNDERWIND ON DRUM:**

The palm is up, facing the drum.
The index finger points at on-winding rope.
The index finger must be closest to the right-side flange.
The wind of the rope must be from right to left along the drum.

FOR LEFT LAY ROPE (USE LEFT HAND)

① **FOR OVERWIND ON DRUM:**

The palm is down, facing the drum.
The index finger points at on-winding rope.
The index finger must be closest to the right-side flange.
The wind of the rope must be from right to left along the drum.

② **FOR UNDERWIND ON DRUM:**

The palm is up, facing the drum.
The index finger points at on-winding rope.
The index finger must be closest to the left-side flange.
The wind of the rope must be from left to right along the drum.

If a smooth-face drum has been cut or scored by an old rope, the methods shown may not apply.

115.289

Figure 11-53.—Drum winding diagrams for selection of proper lay of rope.

safeguard against kinking, NEVER unreel wire rope from a reel that is stationary.

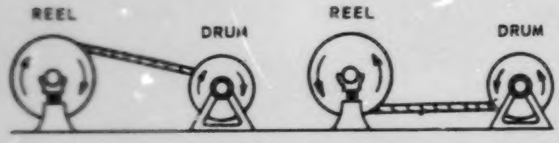
To uncoil a small coil of wire rope, simply stand the coil on edge and roll it along the ground like a wheel or hoop, as illustrated in figure 11-52. NEVER lay the coil flat on the floor or ground and uncoil it by pulling on the end, because either of these actions is likely to cause kinks or twists in the rope.

To re-reel wire rope back onto a reel or a drum you may have difficulty unless you remember that it tends to roll in the opposite direction of the lay. A right-lay wire rope, for example, tends to roll to the left.

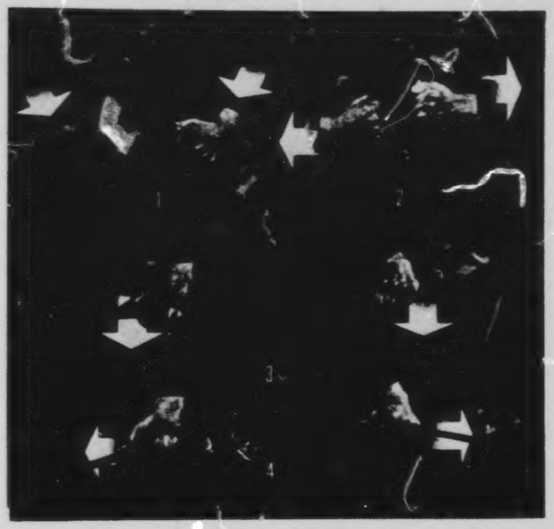
Closely observe figure 11-53, which shows drum winding diagrams for selection of the proper lay of rope. When putting wire rope onto a drum, you should have no trouble if you are familiar with the methods of overwinding and underwinding shown in the illustration. When wire rope is run off one reel onto another reel, or onto a winch or drum, it should be run from TOP TO TOP or from BOTTOM TO BOTTOM, as shown in figure 11-54.

If a wire rope should form a LOOP, never try to pull it out by putting strain on either part. As soon as a loop is noticed, uncross the ends by pushing them apart. (See step 1 in fig. 11-55.) This reverses the process that started the loop. Now, turn the bent portion over and place it on your knee or some firm object and push downward until the loop straightens out somewhat. Then lay it on a flat surface and pound it smooth with a wooden mallet.

If a heavy strain has been put on a wire rope with a KINK in it, the rope can no longer be trusted. Cut out the kinked part and have the ends spliced together by the Steelworkers or replace the wire rope altogether.



80.18
Figure 11-54.—Transferring wire from reel to drum.

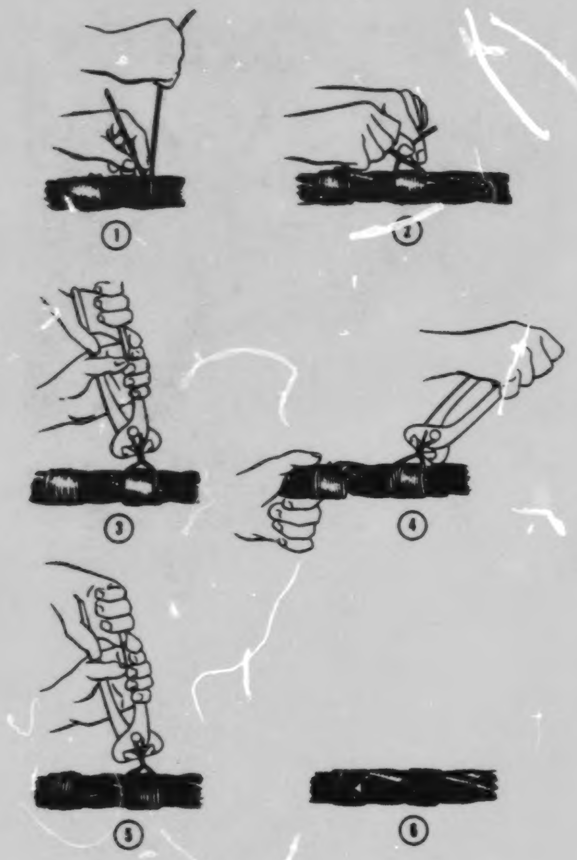


80.20
Figure 11-55.—The correct way to take out a loop in wire rope.

Whenever possible, drums, sheaves, and blocks used with wire rope should be placed so as to avoid REVERSE or S-shaped BENDS. Reverse bends cause an unnecessary amount of shifting of the individual wires and strands, increasing wear and fatigue. Where a reverse bend is necessary, the drums and blocks affecting the reversal should be of larger diameter than that ordinarily used and should be spaced as far apart as possible.

It is not possible to prescribe an absolute minimum size of WIRE ROPE SHEAVES, owing to the number of factors involved. Experience has shown, however, that the diameter of a sheave should NEVER BE LESS THAN 20 TIMES THE DIAMETER OF THE WIRE ROPE. An exception to this is 6 x 37 wire, for which a smaller sheave can be used because of the greater flexibility of this wire rope. The stiffer the wire rope, the larger the sheave diameter required.

Great care is exercised in the manufacture of wire rope to lay each wire in the strand and each strand in the rope under uniform tension. If the ends of the rope are not secured properly, the



56.220

Figure 11-56.—Putting a seizing on wire rope.

original balance of tension will be disturbed and maximum service will not be obtained, because some strands will carry a greater portion of the load than others. Before CUTTING steel wire rope, place three sets of SEIZING on each side of the point where the rope is to be cut. A rule of thumb for determining the size, number, and distance between seizings is as follow:

1 x the diameter for the width of the seizing

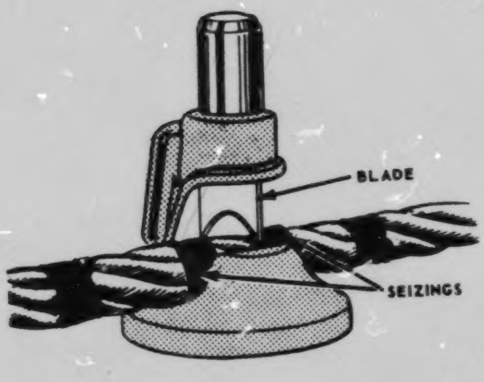
2 x the diameter for the distance between seizings

3 x the diameter for the number of seizings

For permanent seizings the seizing wire should be inserted through the wire rope and then laid along in the valley between strands for the width of the seizing. Then turns are taken back toward the remaining end.

To make a temporary wire rope seizing, wind on the seizing wire uniformly, using tension on the wire. After taking the required number of turns, as in step 1 in figure 11-56, twist the ends of the wires counterclockwise by hand, so that the twisted portion of the wires is near the middle of the seizing, as in step 2. Grasp ends with nippers or suitable pliers and twist up slack as in step 3. Do not try to tighten seizing by twisting. Draw up on seizing as in step 4. Again twist up the slack as in step 5. Repeat steps 4 and 5 if necessary. Cut ends and pound them down on the rope as in step 6. If the seizing is to be permanent, or if the rope is 1-5/8 inches or more in diameter, use a serving bar or iron to increase tension on the seizing wire when putting on the turns.

Wire rope can be cut successfully by a number of methods. One effective yet simple method is that of using a hammer-type wire rope cutter. (See fig. 11-57.) (Remember that all wire must be seized before it is cut.) For best results in using this method, place the rope in the bottom of the cutter, as illustrated, so that the blade comes between the two central seizings.



115.176

Figure 11-57.—Hammer-type wire rope cutter.

With the blade down against the rope at the location of the cut, strike the top of the blade sharply several times with a sledge hammer.

Wire rope can be cut easily with a hydraulic wire rope cutter. This device works basically like a hydraulic jack; as you pump the handle, a cutter severs the wire rope.

Bolt cutters are only suitable for cutting wire of fairly small diameter, but the cutting torch will cut wire of any diameter. Other cutting tools include the hacksaw and cold chisel, but with them the cutting operation is slower and more difficult.

Wire rope bending around winch drums and sheaves will wear like any other metal. Deterioration caused by corrosion is more dangerous than that caused by wear, simply because corrosion commonly affects the inside wires which makes it more difficult to detect by inspection. Deterioration caused by wear can be detected by examining the outside wires of the wire rope, because these wires become flattened and reduced in diameter as the wire rope wears. Any wire rope in which the outside wires are worn to less than 75 percent of their original diameter should be replaced.

Both internal and external lubrication are required to protect a wire rope against wear and corrosion. Internal lubrication can be properly applied only when the wire rope is being manufactured, and manufacturers customarily coat every wire with a rust-inhibiting lubricant as it is laid into the strand. The core is also lubricated in the course of the manufacturing process.

Lubrication applied in the field is designed not only to maintain surface lubrication, but also to prevent the loss of internal lubrication. The Navy issues a gear oil which is called OIL, GEAR, EXPOSED, HOT an asphaltic petroleum oil which must be heated before using. The oil is issued in 5-lb cans, 35-lb pails, and in 120-lb drums. It can be applied by drawing the wire rope through a trough containing hot lubricant as shown in figure 11-58. Frequency of application depends upon service conditions; as soon as the last coating has appreciably deteriorated, it should be renewed.

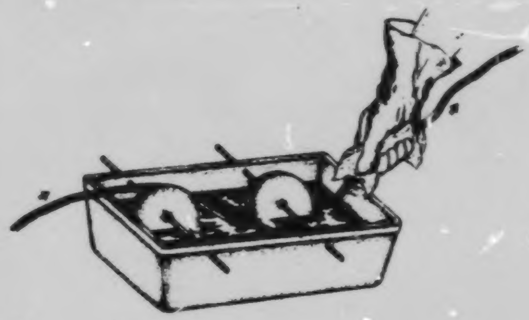
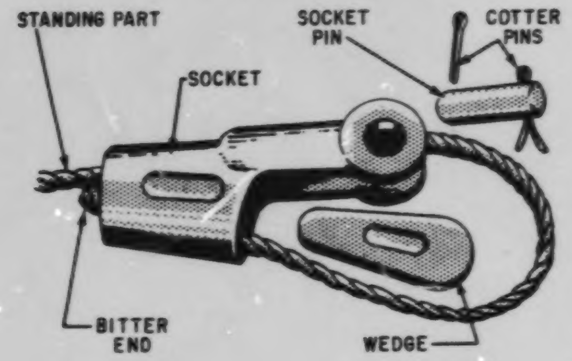

127.49

Figure 11-58.—Method of field lubrication.

As a safety precaution, always wipe off any excess oil when lubricating wire rope. Too much lubricant is liable to get into brakes or clutches, causing them to fail. While in use, the motion of machinery may sling excess oil about, making surfaces, such as catwalks, unsafe to work on. Never lubricate wire rope that comes in contact with soils. The lubricant will pick up fine particles of soil that tend to damage the wire rope because they are abrasive.

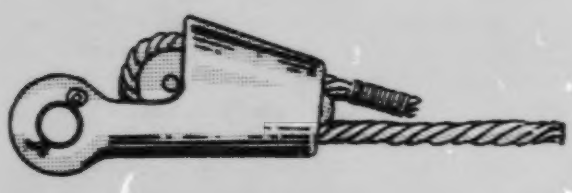
WIRE ROPE ATTACHMENTS

Many attachments can be fitted to the ends of wire rope so that it can be connected to other wire ropes, pad eyes, or equipment. The attachment used most frequently to attach dead ends of wire ropes to pad eyes or similar fittings on earth-moving rigs is the WEDGE SOCKET shown in figure 11-59. The socket is applied to the end of the wire rope as shown in the figure. Remove the pin and knock out the wedge first. Then pass the wire rope up throught the socket and lead enough of it back through the socket to allow at least 2 inches of the dead end to extend below the socket upon completing the attachment, as shown in figure 11-60. Next, replace the wedge, and haul on the dead end of the wire rope until the bight closes around the wedge as shown in figure 11-60. A strain on the standing part will tighten the wedge. A great advantage of the wedge socket is the fact that to



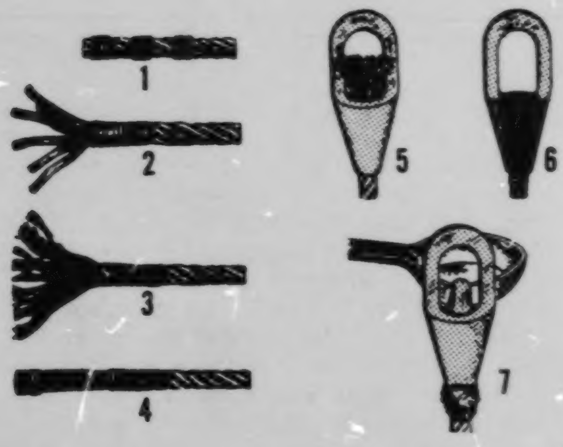
115.177

Figure 11-59.—Parts of a wedge socket.



115.178

Figure 11-60.—Wedge socket attached properly.



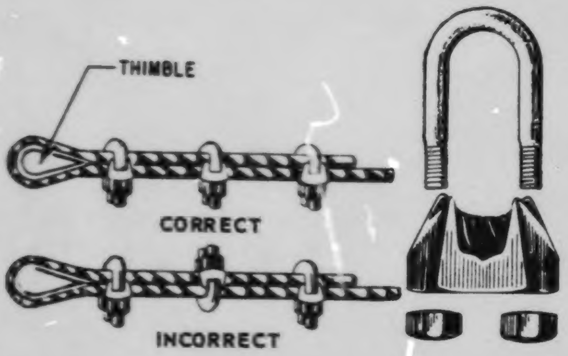
115.179

Figure 11-61.—Speltering a closed or basket socket.

remove it you need only to drive out the wedge. It should be noted, however, that the strength of a wedge-type socket is such that the overall strength of a rope having a socket attachment is reduced by about one-third. The safe working load of the rope must, of course, also be reduced accordingly.

The best method for attaching a closed or open socket is by speltering. The term SPELTERING means to attach the socket to the wire rope by pouring hot zinc. (See fig. 11-61.) Forged steel speltered sockets are as strong as the wire rope itself, and are required on all cranes that are used primarily for lifting personnel, as well as for lifting ammunition, acids, and other extremely dangerous materials. Cranes lifting foodstuff and other general supplies may use forged steel wedge or swaged sockets.

A common method of making an eye in the end of a wire rope is by the use of WIRE ROPE CLIPS like those shown in figure 11-62. The U-shaped part of the clip, with the threaded ends, is called the U-BOLT; the other part is called the SADDLE (OR RODDLE). The saddle is stamped with the diameter of the wire rope the clip will fit. Always place a clip with the U-bolt on the dead end, not on the standing part of the wire rope. If clips are attached incorrectly, the live end of the wire rope will be distorted or will have mashed spots.



56.226

Figure 11-62.—Wire rope clips.

Following is a simple formula for wire rope clips:

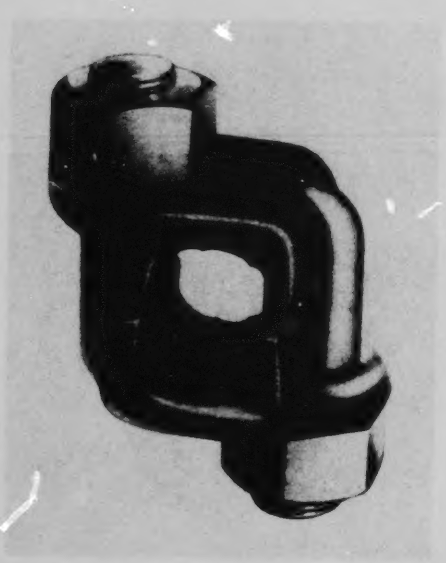
3 x wire rope diameter + 1 = Number of clips

6 x wire rope diameter = Spacing between clips

Another type wire rope clip is the TWIN-BASE clip shown in figure 11-63. Both parts of this clip are shaped to fit the wire rope; consequently, the clip cannot be put on wrong and it is less damaging to wire rope than the U-bolt clip.

It also allows for a clear 360 degree swing with the wrench when the nuts are being tightened. When an eye is made in a wire rope, the metal fitting called a THIMBLE is usually placed in the eye, as shown in figure 11-62, to protect the eye against wear.

After the eye made with clips has received an initial heavy strain, the nuts on the clips must be retightened. Periodic checks should be made afterwards for tightness, and also for damage to the rope that might be caused by the clips.



80.70X

Figure 11-63.—Twin-base wire rope clip.

HEAVY-DUTY AIR COMPRESSORS

In the Naval Construction Force, compressed air is used to inflate tires, to spray paint, to operate pneumatic tools, to clean equipment, to perform various jobs around maintenance shops, to furnish air for underwater divers, and to supply power for drilling equipment.

A compressor is a machine for compressing air from an initial intake pressure to a higher exhaust pressure through reduction in volume. It consists of a driving unit, a compressor unit, and their accessories. The driving unit provides power to operate the compressor and is normally a diesel engine. Compressors used by the Naval Construction Force are slightly different from commercial models. Even though manufactured by different companies, most compressors are quite similar. They are governed by a pressure control system which is adjusted to compress air to a maximum pressure of 100 pounds per square inch. The compressor unit may be of reciprocating, rotary, or screw design.

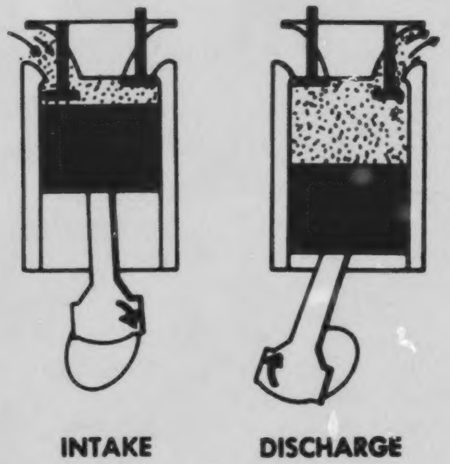
COMPRESSOR DESIGN

The construction of reciprocating compressors is similar to that of an automobile engine. They may be air or liquid cooled. As the piston moves up and down, air flows into the cylinder through the one-way intake valve (fig. 11-64).

As the piston moves upward the intake valve closes and the trapped air is compressed until it exceeds the pressure within the collecting manifold, at which time the discharge valve opens and the compressed air is forced into the air manifold.

The reciprocating compressor is normally connected to an engine through a direct coupling or a clutch. The engine and compressor are separate units.

Rotary compressors have a number of vanes held captive in slots in the rotor and sliding in and out of the slots. Figure 11-65 shows an end view of the vanes in the slots. The rotor revolves about the center of of its shaft which is offset

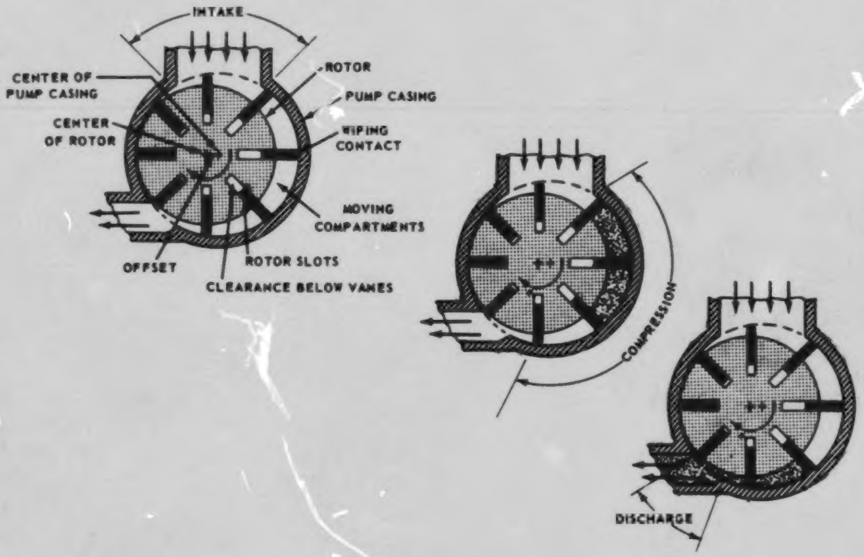

INTAKE
DISCHARGE

54.19

Figure 11-64.—Intake and compression strokes in a reciprocating compressor.

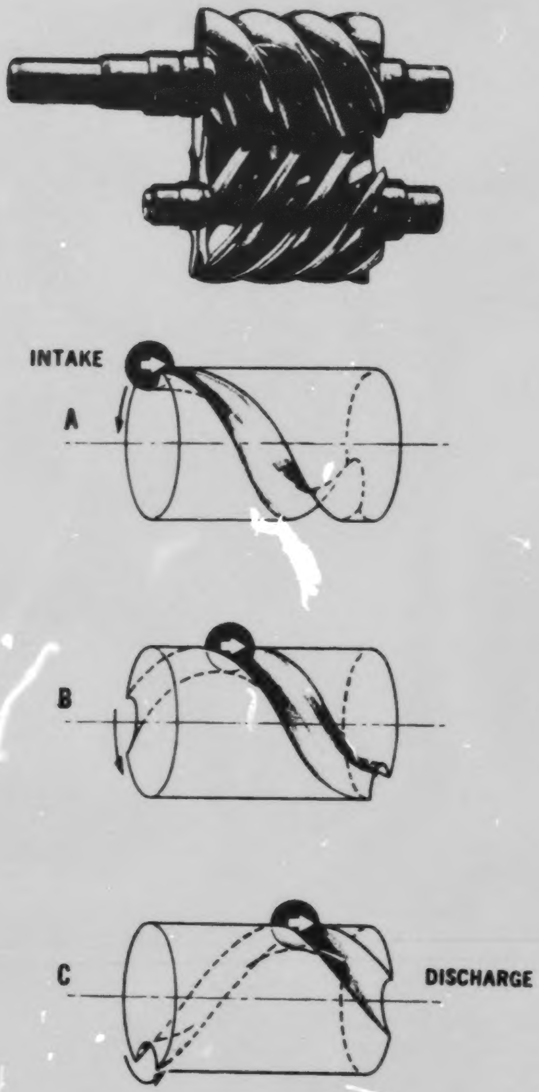
from the center of the pump casing. Centrifugal force acting on the rotating vanes maintains wiping contact between the edge of the vanes and the pump casing. This feature causes the vanes to slide in and out of their slots when the rotor is turning. Notice the variation in the clearance between the vanes and the bottom of the slots as the rotor revolves. The vanes divide the crescent-shaped space, between the offset rotor and the pump casing, into compartments which increase, and then decrease, in size as the rotor rotates. Thus, free air enters each compartment as successive vanes pass across the air intake; the air is carried around in each compartment and is discharged at a higher pressure due to the decreasing size (volume) of the moving compartments as they progress from one end to the other of the crescent shaped space. The compressor is lubricated by oil circulating throughout the unit. All oil is removed from the air by an oil separator before the compressed air leaves the service valves.

The screw compressors are direct-drive, single stage machines, with two rugged, precisely matched spiral-grooved rotors (fig. 11-66). The rotors provide positive-displacement internal compression, smoothly and without surging. Oil is injected between the rotors to cool the air and seal against slip losses. The oil that mixes with the air during compression passes into the receiver-separator, where it is removed and returned to the oil cooler.


INTAKE
CENTER OF PUMP CASING
CENTER OF ROTOR
ROTOR
PUMP CASING
WIPING CONTACT
MOVING COMPARTMENTS
OFFSET
ROTOR SLOTS
CLEARANCE BELOW VANES
COMPRESSION
DISCHARGE

54.19

Figure 11-65.—Compression cycle in rotary compressor.



54.19

Figure 11-66.–Compression cycle in screw compressor.

All large volume compressors have protection devices that will shut them down automatically when the engine oil pressure drops below a certain point, when the engine coolant rises above a certain temperature, when the compressor discharge rises above a certain temperature, or when any of the protective safety circuits develop a malfunction.

Other features that may be observed in the operation of air compressors is a governor system whereby the engine speed is reduced when less than full air delivery is used. An engine and compression control system prevents excessive buildup in the receiver.

Air compressors, reciprocating, rotary and screw, are classed as either single stage or multistage. In a single stage compressor there is but one compressing element which compresses the air from the initial intake pressure to the final discharge pressure in one step. In the multistage machine there is more than one compressing element. The first stage compresses the air to an intermediate pressure, thence to one or more additional stages to be compressed to final discharge pressure. The multistage system is more efficient than the single stages, thus reducing a premature buildup of pressure due to temperature.

Intercoolers

When air is compressed, heat is generated. This heat causes the air to expand, thus necessitating an increase in the power required for further compression. If this heat is successfully removed between stages of compression, the total power required for additional compression may be reduced by as much as 15 percent. In multistage reciprocating compressors, this heat is removed by means of intercoolers, which are heat exchangers placed between each compression stage. Rotary air compressors are cooled by oil and do not use intercoolers.

Aftercoolers

It is obvious that the presence of water or moisture in an air transmission line is not desirable. The water is carried along through the line into the tool where the water washes away the lubricating oil thus causing the tool to run sluggishly and increases maintenance. The effect is particulary pronounced in the case of high speed tools where the wearing surfaces are limited in size and excessive wear reduces efficiency by creating internal air leakage. Further problems may result from the decrease in temperature caused by the sudden expansion of air at the tool. This low temperature creates condensation which freezes around the valves, ports, and outlets. This condition obviously impairs the operational efficiency of the tool and cannot be allowed. The most satisfactory means of minimizing these conditions is the removal of the moisture from the air immediately after compression and before the air enters the distribution system. This may be accomplished in reciprocating compressors through use of an aftercooler which is an air radiator that transfers heat from the compressed air to the atmosphere. The aftercooler reduces the temperature of the compressed air to the condensation point where most of the moisture is removed. Cooling the air not only eliminates the difficulties which moisture causes at points where air is used, but also insures better distribution.

Receivers

The receiver tank is of welded steel construction and is installed on the discharge side of the compressor. It acts as a surge tank as well as a condensation chamber for the removal of oil and water vapors. It stores enough air during operation to actuate the pressure control system, and is fitted with at least one service valve, a drain or blow-down valve, and a safety valve.

Pressure Control System

All military construction compressors are governed by a pressure control unit. In a reciprocating compressor the pressure control system causes the engine to idle and the suction valves to remain open when the pressure reaches a set maximum, thus making the compressor unit inoperative. When the air pressure drops below a set minimum, the pressure control unit causes the engine to increase speed and the suction valves to close, thus resuming the compression cycle. The rotary compressor output is governed by varying the engine speed. The engine will operate at the speed required to compress enough air to supply the demand at a fairly constant pressure. When the engine has slowed to idling speed as a result of low demand, a valve throttles the amount of free air which may enter the compressor.

The screw compressor output is governed by automatic control which provides smooth, stepless capacity regulation from full load to no load in response to the demand for air. From a full load down to no load is accomplished by a floating-speed engine control in combination with the variable-inlet compressor.

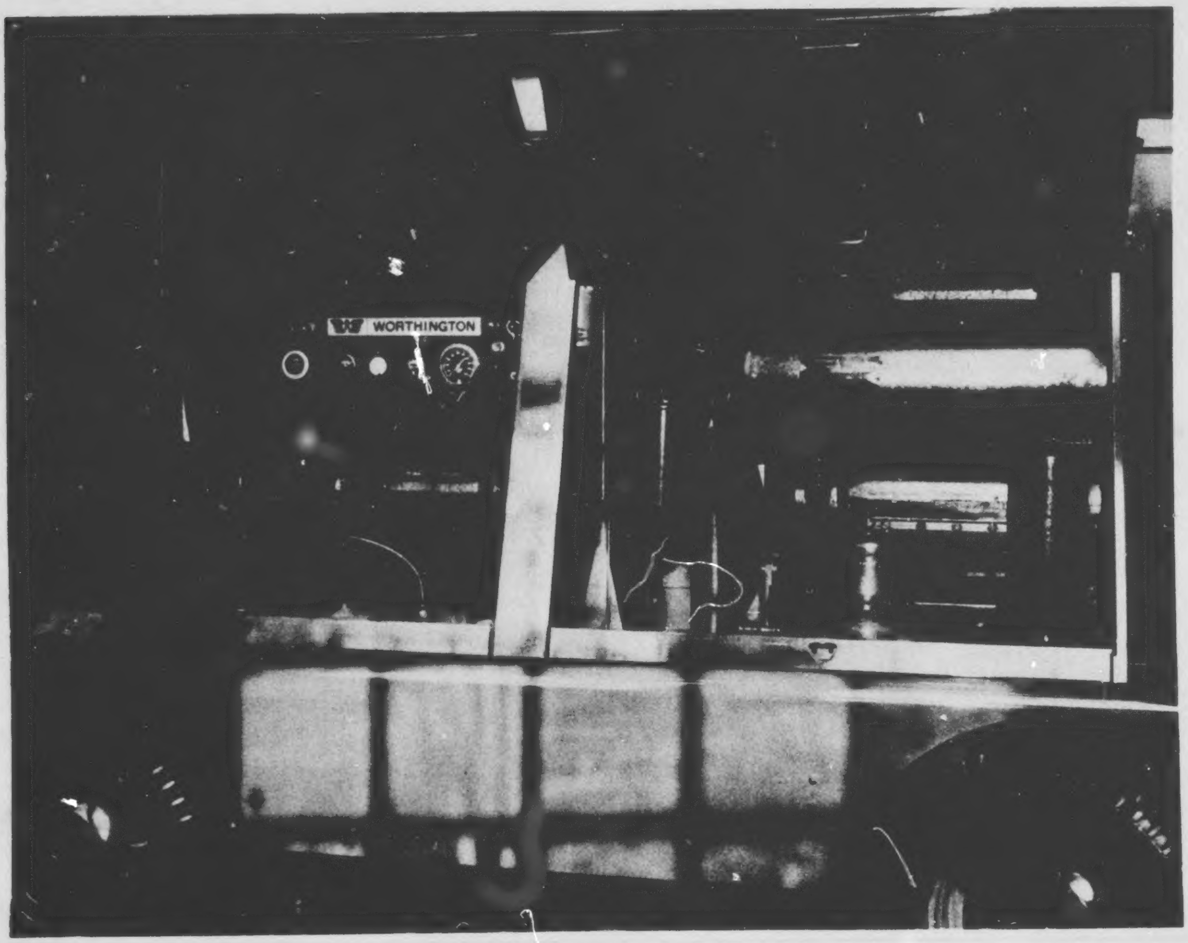
AIR COMPRESSOR MAINTENANCE

The Worthington portable air compressor shown in figure 11-67 is representative of rotary compressors that have single stages and sliding vane rotors. This compressor has several built-in features that make it easy to maintain. These include an automatic blowdown valve for releasing air pressure when the engine is stopped; a means for draining moisture that accumulates in the receiver tank; a drain cock (fig. 11-68) at the bottom of the compressor suction control and engine speed control; a drain cock on the piping at the bottom of the oil storage tank; an air cleaner service indicator (fig. 11-69) to show when the filter needs changing; and a demister, or special filter that separates lubricating oil from compressed air.

The operation of a rotary air compressor should be free of trouble if it is maintained and serviced properly. Your main concerns in taking care of the compressor are keeping the air and lubricating oil clean and adjusting the pneumatic controls (fig. 11-68).

AIR CLEANER SERVICING

The air cleaner contains a two-stage, dry filter element that is replaced when dirty. It is time to change the filter when a red band appears in the sight glass of the air cleaner service indicator. If you can see this band while



115.377X

Figure 11-67.—Worthington 600 cfm portable rotary air compressor.

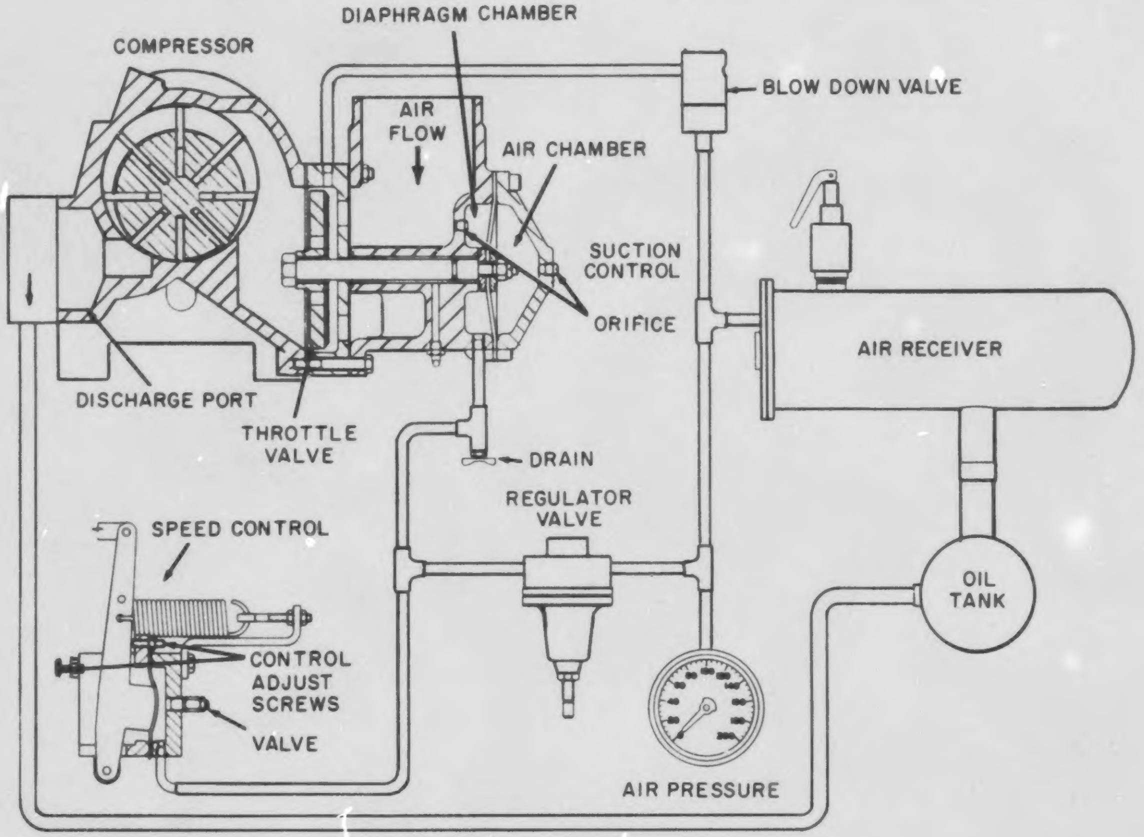
the compressor is operating, secure the compressor and remove the filter element. Before installing a new element, clean any accumulation of dust or other foreign matter from the filter housing. A pipe leading from the filter housing and connected to the engine's exhaust system removes the dirt from the first stage of the filter element.

OIL FILTER SERVICING

The oil filter is serviced each time the compressor oil is changed. Under normal operating conditions, this takes place at approximately 500 operating hours; more frequently under severe conditions. The oil filter is a replaceable cartridge.

DEMISTER SERVICING

The demister is located inside the receiver tank. Any sign of oil in the air at the service valves is reason enough to replace the demister. You can reach it after removing the plate on the end of the receiver tank.


DIAPHRAGM CHAMBER
COMPRESSOR
BLOW DOWN VALVE
AIR FLOW
AIR CHAMBER
SUCTION CONTROL
ORIFICE
AIR RECEIVER
DISCHARGE PORT
THROTTLE VALVE
DRAIN
REGULATOR VALVE
SPEED CONTROL
OIL TANK
CONTROL ADJUST SCREWS
VALVE
AIR PRESSURE

115.380X

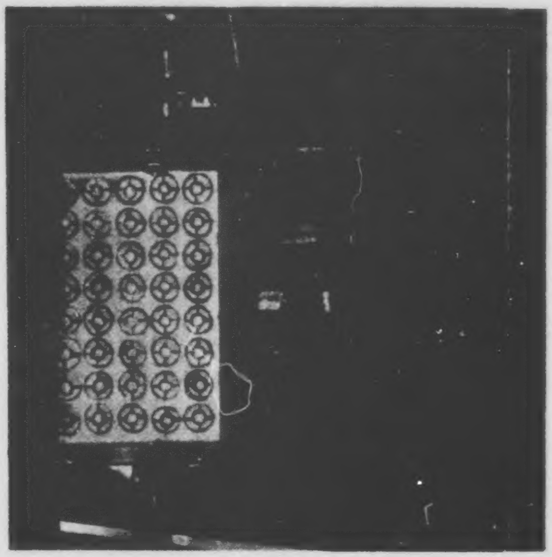
Figure 11-68.—Pneumatic controls.

PNEUMATIC CONTROLS SERVICING AND ADJUSTMENT

Servicing the compressor controls is limited to lubrication of the linkage that connects the engine throttle to the speed control and the suction control valve shaft. However, they have to be adjusted occasionally.

Speed Control

The speed control is adjusted for either maximum or minimum speed. Since the compressor operates at the same speed as the engine, this control limits the operating speeds of the engine and compressor. The spring attached to the speed control lever tries to hold the engine at high idle. Air pressure from the receiver tank acting on the diaphragm inside the speed control counteracts spring tension and causes the lever to move against the low-speed stop screw. Any drop in air pressure within the receiver allows the spring's tension to move the lever and increase the engine speed enough to provide the desired quantity of air. The increased speed also maintains a stable pressure in the receiver. When large volumes of air are used, or the service valves are fully open, low air pressure at the diaphragm permits the spring to hold the lever against the high idle stop screw. The only other maintenance needed on the speed control is replacement of the diaphrgam.



115.379X

Figure 11-69.—Air cleaner.

Suction Control

The suction control valve, located at the compressor inlet, regulates the amount of air entering the compressor. This valve, together with the compressor speed control, varies the output of the compressor from minimum to maximum volume. Air pressure acting on the suction control diaphragm causes the shaft and throttle valve to vary the opening to the compressor. This valve closes when the air pressure in the receiver is at maximum or 100 psi. Failure of this valve to close when engine speed is reduced to idle will stall the engine.

This failure is sometimes caused by a sticking suction control valve. If it sticks but the throttle valve remains open or fails to seal the opening, remove the intake body containing the throttle valve. Disassemble the valve and replace any faulty components. Make sure you cover the compressor inlet after removing the intake body to keep out any foreign matter. Carefully inspect the throttle plate and diaphragm for damage. These parts are not repairable and must be replaced when faulty. When reassembling, insure that the connections in the intake piping are tight and leak free.

THERMOSTAT REPLACEMENT

An overheated compressor will automatically shut down the engine. A thermostat located in the piping near the oil filter regulates the flow of oil to the cooler and insures adequate cooling. If the thermostat is defective, replace it.

DISASSEMBLY

Lubrication of the compressor is provided by pressure through orifices in the compressor body and end plates. Poor lubrication of the compressor causes overheating of the discharge air from the compressor. The compressor must be partially disassembled to inspect for faulty lubrication. In disassembling the compressor, follow the instructions given in the manufacturer's service manual. Access to the compressor is through an end plate which must be removed. The vanes can then be withdrawn and the compressor housing inspected. A slightly scored housing can be cleaned up and the unit will function normally. If heavily scored, the housing must be replaced. Also, examine the vanes for wear, thickness, and length. Replace them if they don't measure up to the manufacturer's specifications. While the compressor is disassembled, clean out the orifices to insure the vanes will get enough oil while the compressor is operating.

CHAPTER 12

MAINTENANCE

Maintenance is the care exercised and the work performed to retain vehicles and equipment in safe and serviceable operating condition during their normal service life. The purpose of the Navy's maintenance program is to effect economy and dependability in the use of equipment and to insure continuity of operation. It is not intended that vehicles be maintained in a like-new condition during this period.

In this chapter we will discuss maintenance from an organizational viewpoint, dealing primarily with maintenance administration and maintenance support. Lubrication, one of the most important phases of a sound maintenance program, will also be discussed.

MAINTENANCE ADMINISTRATION

Administrative guidelines concerning equipment maintenance at permanent shore activities are contained in NAVFAC P-300, *Management of Transportation Equipment*. Guidelines for all units of the Naval Construction Force (NCF) are contained in the NCF *Equipment Management Manual*, NAVFAC P-404.

CATEGORIES OF MAINTENANCE

There are three categories or levels of maintenance presently used in the Civil Engineering Support Equipment (CESE) maintenance system: ORGANIZATIONAL, INTERMEDIATE, and DEPOT. The type of repairs performed is determined by the nature of the repair; the amount of support available (spare parts, tools, personnel, and so on); and the tactical situation. An activity's range of repair parts support is keyed to the authorized level of maintenance. The four different levels of repair parts support that can be assigned are described in the Maintenance Support section of this chapter.

Organizational Maintenance

Organizational maintenance normally consists of proper operator's maintenance, safety and serviceability inspections, lubrications, minor adjustments, and services. Activities accomplishing only organizational maintenance will normally be provided with organizational ("O") level repair parts support. Organizational maintenance is divided into operator and preventive maintenance.

OPERATOR'S MAINTENANCE is that maintenance required by an operator to keep his assigned equipment in a clean, safe and serviceable condition.

PREVENTIVE MAINTENANCE is that maintenance which is scheduled with the main objective of reducing equipment downtime and unnecessary repairs. Preventive maintenance (PM) normally consists of lubrication and minor services, and adjustments beyond the scope of those required under operator's maintenance. The operator assigned to the equipment being PM'ed should always give a hand unless specifically directed otherwise.

Intermediate Maintenance

Intermediate maintenance is the responsibility of, and is performed in, a mobile, semimobile, permanent, or semipermanent maintenance shop. The extent of intermediate maintenance encompasses all repairs up to and including overhaul of individual assemblies, subassemblies, and components. However, extensive repair or rebuilding of major assemblies should not be attempted on equipment without prior approval of higher authority. Intermediate maintenance requires a higher degree of skill than organizational maintenance and is authorized a larger assortment of repair parts and more precision tools and testing equipment.

Depot Maintenance

Depot maintenance is performed on equipment requiring major overhaul or comprehensive restoration that will return the piece of equipment to a like new condition. Depot level maintenance employs production line and assembly line methods whenever practical. Activities assigned depot level maintenance will assist activities assigned the lower categories of maintenance wherever possible.

Normally, as a CM3 or CM2, you will only be concerned with organizational and intermediate maintenance. Most of the SEABEE's depot maintenance is performed by overhaul facilities located at Port Hueneme, California and Gulfport, Mississippi.

MAINTENANCE SCHEDULING

The only type of maintenance that can be performed on a regular schedule is Preventive Maintenance. A dynamic PM program will reduce equipment downtime and prevent unexpected equipment failure. PM scheduling provides a balanced shop workload, thus reducing the size of the work force required. Once an activity's PM schedule has been established, only the maintenance supervisor can authorize deviations. The PM scheduling system used in the NCF is the system we will discuss. The standard interval between PM's is 40 working days.

PM Groups

PM groups are scheduling units, into which all of an activity's equipment is evenly distributed. Each item of CESE must be assigned to at least one PM group. The equipment should be distributed evenly throughout the 40 PM groups, so that a minimum number of similar pieces of equipment are out of service at any one time. The normal grouping would work like this: if there are 10 dump trucks within the inventory, one should be assigned to every fourth PM group; if there are four water distributors, assign one to every tenth PM group, and so on. The equipment should be grouped so that units which normally work together are scheduled for PM together; for example, semitrailers with truck tractors, scrapers with tractors, and so on. Activities should initially assign each piece of equipment to one PM group. After the system is established and operating, the maintenance supervisor should review its effectiveness and REDUCE the time intervals for certain pieces of equipment if necessary.

NOTE: The time interval is NEVER INCREASED beyond 40 work days.

Preventive Maintenance Scheduling

A Preventive Maintenance inspection schedule, such as that shown in figure 12-1, is established by the PM clerk annually. A new schedule is required each year as the schedules are based on the workdays in each calendar year. The workdays on the schedule must correspond to the unit's actual workdays; i.e., if you work a 6-day week, enter 6 days; omit holidays. The PM groups are numbered vertically down the first column. Figure 12-1 depicts the standard 40 PM group concept arranged for a 5-day workweek. The dates of the workdays of January are then listed consecutively in the January column. After January's last workday is entered, continue with February's workdays in the February column, and so forth. After completion, the schedule shows the workdays on which each PM group is due for inspection. For example, figure 12-1 shows PM group 5 is due on January 8, March 6, May 1, June 27, August 23, October 23, and December 19.

MAINTENANCE INSPECTIONS

The objective of maintenance inspections is to keep equipment in a safe and serviceable

GROUP	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
1	2	28		25		21		17		16		13
2	3		1	26		22		20		17		14
3	4		2	27		25		21		18		17
4	5		5	30		26		22		19		18
5	8		6		1	27		23		23		19
6	9		7		2	28		24		24		20
7	10		8		3	29		27		25		21
8	11		9		4		2	28		26		26
9	12		12		7		3	29		29		27
10	15		13		8		5	30		30		28
11	16		14		9		6	31		31		31
12	17		15		10		9		4		1	
13	18		16		11		10		5		2	
14	19		19		14		11		6		5	
15	22		20		15		12		7		6	
16	23		21		16		13		10		7	
17	24		22		17		16		11		8	
18	25		23		18		17		12		9	
19	26		26		21		18		13		12	
20	29		27		22		19		14		13	
21	30		28		23		20		17		14	
22	31		29		24		23		18		15	
23		1	30		25		24		19		16	
24		2		2	29		25		20		19	
25		5		3	30		26		21		20	
26		6		4	31		27		24		21	
27		7		5		1	30		25		23	
28		8		6		4	31		26		26	
29		9		9		5		1	27		27	
30		12		10		6		2	28		28	
31		13		11		7		3		1	29	
32		14		12		8		6		2	30	
33		15		13		11		7		3		3
34		16		16		12		8		4		4
35		20		17		13		9		5		5
36		21		18		14		10		9		6
37		22		19		15		13		10		7
38		23		20		18		14		11		10
39		26		23		19		15		12		11
40		27		24		20		16		15		12

2.467

Figure 12-1.—Sample PM inspection schedule.

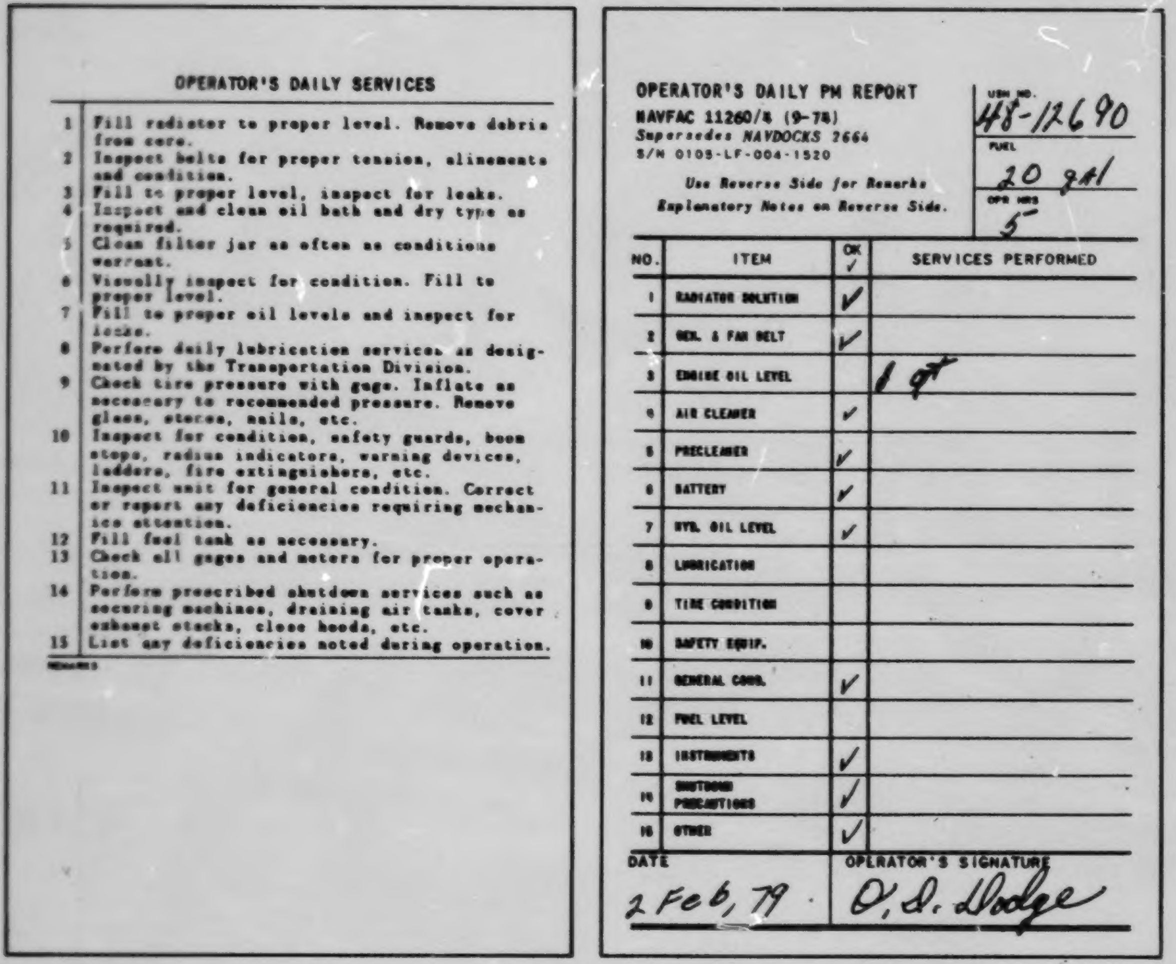
condition at all times by detecting minor deficiencies before they develop into costly major repairs.

Operator's Inspections

The first sign of vehicle trouble is usually detected by the operator during one of his three daily inspections: before, during, and after operations.

The BEFORE OPERATION inspection consists of the operator's inspecting and servicing the items listed on the Operator's Daily PM Report, NAVFAC 11260/4 (fig. 12-2) for construction equipment and the Operator's Inspection Guide and Trouble Report, NAVFAC 9-11240/13 (fig. 12-3) for automotive equipment. If a defect is discovered, the equipment SHOULD NOT BE OPERATED. The defect must be reported to the dispatcher, who in turn will report it to the maintenance section.

The DURING OPERATION inspection consists of the operator's using his sense of smell, sight, and touch to detect improper



OPERATOR'S DAILY SERVICES

1 Fill radiator to proper level. Remove debris from core.
2 Inspect belts for proper tension, alinements and condition.
3 Fill to proper level, inspect for leaks.
4 Inspect and clean oil bath and dry type as required.
5 Clean filter jar as often as conditions warrant.
6 Visually inspect for condition. Fill to proper level.
7 Fill to proper oil levels and inspect for leaks.
8 Perform daily lubrication services as designated by the Transportation Division.
9 Check tire pressure with gage. Inflate as necessary to recommended pressure. Remove glass, stones, nails, etc.
10 Inspect for condition, safety guards, boom stops, radius indicators, warning devices, ladders, fire extinguishers, etc.
11 Inspect unit for general condition. Correct or report any deficiencies requiring mechanics attention.
12 Fill fuel tank as necessary.
13 Check all gages and meters for proper operation.
14 Perform prescribed shutdown services such as securing machines, draining air tanks, cover exhaust stacks, close hoods, etc.
15 List any deficiencies noted during operation.

REMARKS

OPERATOR'S DAILY PM REPORT
NAVFAC 11260/4 (9-74)
Supersedes NAVDOCKS 2664
S/N 0105-LF-004-1520

Use Reverse Side for Remarks
Explanatory Notes on Reverse Side.

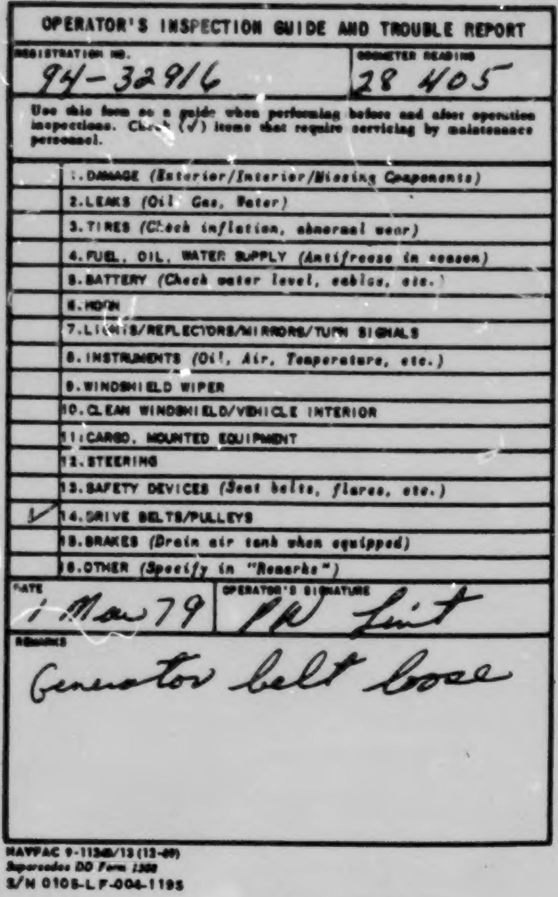
USN NO. 48-12690
FUEL 20 gal
OPR HRS 5

NO.	ITEM	OK ✓	SERVICES PERFORMED
1	RADIATOR SOLUTION	✓	
2	GEN. & FAN BELT	✓	
3	ENGINE OIL LEVEL		1 qt
4	AIR CLEANER	✓	
5	PRECLEANER	✓	
6	BATTERY	✓	
7	HYD. OIL LEVEL	✓	
8	LUBRICATION		
9	TIRE CONDITION		
10	SAFETY EQUIP.		
11	GENERAL COND.	✓	
12	FUEL LEVEL		
13	INSTRUMENTS	✓	
14	SHUTDOWN PRECAUTIONS	✓	
15	OTHER	✓	

DATE 2 Feb, 79
OPERATOR'S SIGNATURE O. D. Dodge

87.323

Figure 12-2.—Operator's Daily PM Report, NAVFAC 11260/4.



OPERATOR'S INSPECTION GUIDE AND TROUBLE REPORT

REGISTRATION NO. 94-32916

ODOMETER READING 28 405

Use this form as a guide when performing before and after operation inspections. Check (✓) items that require servicing by maintenance personnel.

☐	1. DAMAGE (Exterior/Interior/Missing Components)
☐	2. LEAKS (Oil, Gas, Water)
☐	3. TIRES (Check inflation, abnormal wear)
☐	4. FUEL, OIL, WATER SUPPLY (Antifreeze in season)
☐	5. BATTERY (Check water level, cables, etc.)
☐	6. HORN
☐	7. LIGHTS/REFLECTORS/MIRRORS/TURN SIGNALS
☐	8. INSTRUMENTS (Oil, Air, Temperature, etc.)
☐	9. WINDSHIELD WIPER
☐	10. CLEAN WINDSHIELD/VEHICLE INTERIOR
☐	11. CARGO, MOUNTED EQUIPMENT
☐	12. STEERING
☐	13. SAFETY DEVICES (Seat belts, flares, etc.)
☑	14. DRIVE BELTS/PULLEYS
☐	15. BRAKES (Drain air tank when equipped)
☐	16. OTHER (Specify in "Remarks")

DATE 1 Mar 79

OPERATOR'S SIGNATURE PW Lint

REMARKS Generator belt loose

NAVFAC 9-11240/13 (12-69)
Supersedes DD Form 1300
S/N 0105-LF-004-1195

29.50

Figure 12-3.—Operator's Inspection Guide and Trouble Report, NAVFAC 9-11240/13.

operation. If a defect is discovered during operation, the equipment should be secured and the problem reported to his supervisor or the dispatcher.

The AFTER OPERATION inspection consists of the operator's looking over the equipment as he performs the established shutdown procedures and reporting any defects to the dispatcher.

Safety Inspections

The Navy requires that each motor vehicle receive a safety inspection at least once every 6 months or 6000 miles, whichever occurs first. In addition to the above requirements, it is a good practice to give every vehicle in the shop a safety inspection before it is turned out. This should be included in the inspection conducted at scheduled maintenance services. Some of the more important items to be inspected are listed below:

Brakes	• Test to determine if the brakes are functioning properly.
	• Check the brake pedal free travel as required.
	• Remove the right front brake drum; inspect it for wear or cracking; inspect the lining for excessive wear; check the wheel cylinders for leaks and deterioration (to be performed annually and/or as required to comply with state and local inspection regulations).
	• Check the fluid level and all the hydraulic brake lines for leaks.
	• On airbrake systems inspect the airbrake accessories and all air lines and air tanks for leaks and deterioration; check the airbrake instrument controls and air valves.
Lights	• Check all the lights, signals, and reflectors.
	• Check the condition of the trailer jumper cable.
	• Check the headlights for proper alinement.

Instruments, Controls, and Warning Devices	• Check all the instruments, gages, mirrors, switches, controls, horns, and warning devices for proper functioning and damage.
Exhaust System	• Check the muffler, exhaust, and tailpipes and all connections for leaks.
Steering System	• Check all steering devices and linkage for wear and damage.
Seat Belts	• Check all safety belts for wear and proper mounting.
Fifth Wheel and Trailer	• Check the operation of the fifth wheel mounting bolts or clamps and safety lock. Check the trailer kingpin for wear or damage.
Tires	• Check all the tires for damage and excess wear.
	• Remove and replace all tires with 1/16 of an inch or less of tread. Check the wheel lug nuts for tightness.
Windshield Wipers, Glass and Defrosters	• Check the wipers, glass, and defroster for proper operation, wear, damage, and deterioration.

Type "A" PM Inspections

Type "A" PM's are scheduled at intervals of 40 working days, regardless of usage. This type of inspection is performed until the equipment qualifies for a type "B". These inspections are particularly critical on low usage equipment, such as equipment on a standby status to insure that it does not deteriorate. Type "A" PM's consist primarily of safety and serviceability inspections and are performed by utilizing the appropriate portions of appendix II or III.

Type "B" PM Inspections

Type "B" PM's are performed at intervals of 2000 miles, 120 hours, or after two consecutive "A" PM's. Type "B" inspections are more detailed than type "A" inspections and are performed utilizing the appropriate portions of appendix II or III.

Type "C" PM Inspection

Type "C" PM's will be performed as determined by the maintenance supervisor. It is his duty to insure that the waivering of "C" PM requirements will increase equipment availability without sacrificing equipment condition. Type "C" PM's are very comprehensive inspections and will be performed by utilizing all items of appendix II or III, as appropriate.

Deadline Inspections

Deadline inspections are particularly critical to insure that equipment does not deteriorate. Deadline inspections may be performed at each regularly scheduled PM due date or more frequently, if so determined by the maintenance supervisor. As a minimum, deadline inspections insure that: all openings are covered and weathertight; all machine surfaces are preserved; all disassembled components are tagged, covered, and stored; and no cannibalization (removal of components) has taken place since the last inspection. Deadline inspections should include any possible cycling (checking components for proper operation) of the deadlined item; i.e., if a truck is down for an axle you can still start the engine and insure that it runs O.K. If cycling is accomplished, insure that all required representation is accomplished. Equipment is considered deadlined when it will not perform as designed or is in need of parts which are not on hand.

PM RECORD CARDS

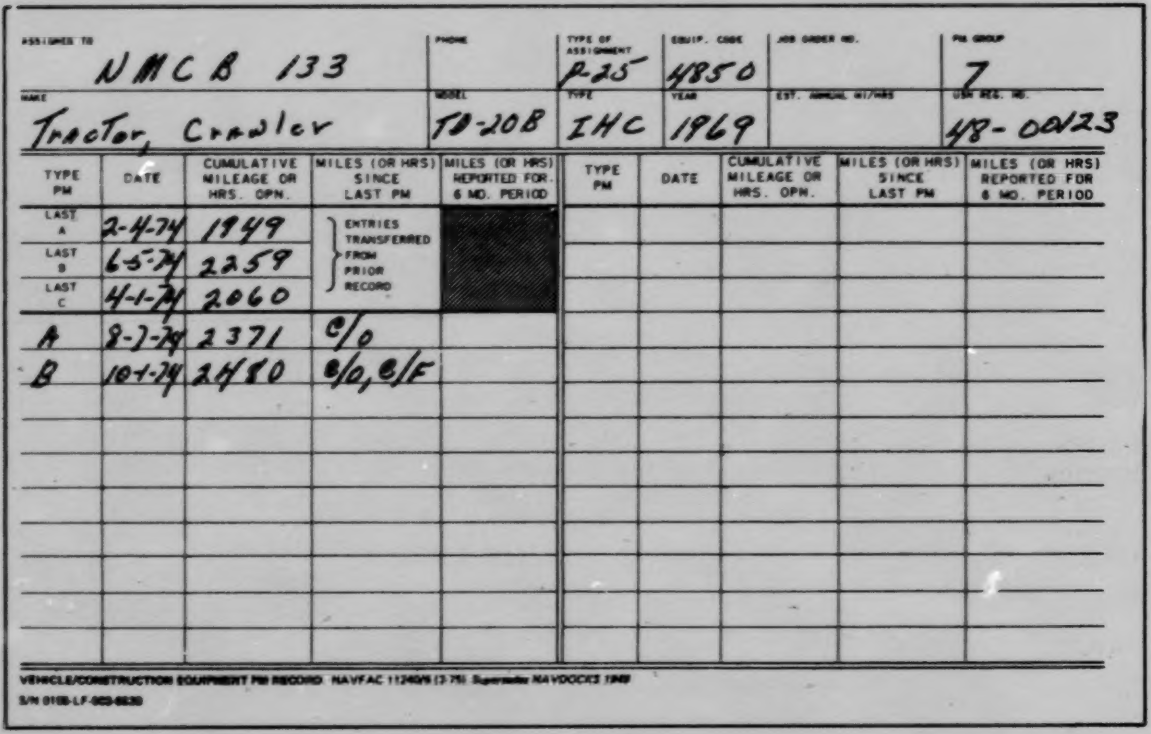
A Preventive Maintenance Record Card, NAVDOCKS 1949, must be accurately maintained for each item of assigned equipment. (See figure 12-4.) A PM record card on a particular vehicle will contain the vehicle's preventive maintenance history in chronological order and necessary information to assist the PM clerk in preparing Equipment Repair Orders. NAVDOCKS 1949 cards are maintained in PM group sequence in a separate file. Equipment assigned to more than one PM group will have a dummy PM record card filed in the extra PM group (or groups). The PM clerk records the following information on the PM record card from completed PM Equipment Repair Orders: type of PM service performed, date it was performed, and accumulative miles/hours. Engine oil or filter changes are indicated by entering "O/C" or "F/C". PM record cards are returned to the appropriate equipment history jacket when the vehicle is transferred.

REPAIR ORDERS

The Navy uses repair orders to specify, authorize, and control repairs on all USN-numbered equipment. The repair orders also serve as a reporting document from which information can be extracted to provide an activity with a complete picture of how their maintenance program is doing and also provide complete historical cost and utilization information for each piece of CESE equipment. Therefore, the information contained on repair orders must be neat, complete, and accurate. This cannot be overemphasized.

Shop Repair Orders

The shop repair order (SRO) and its continuation sheet (fig. 12-5 and 12-6) are used mainly in Public Works activities. The SRO is a



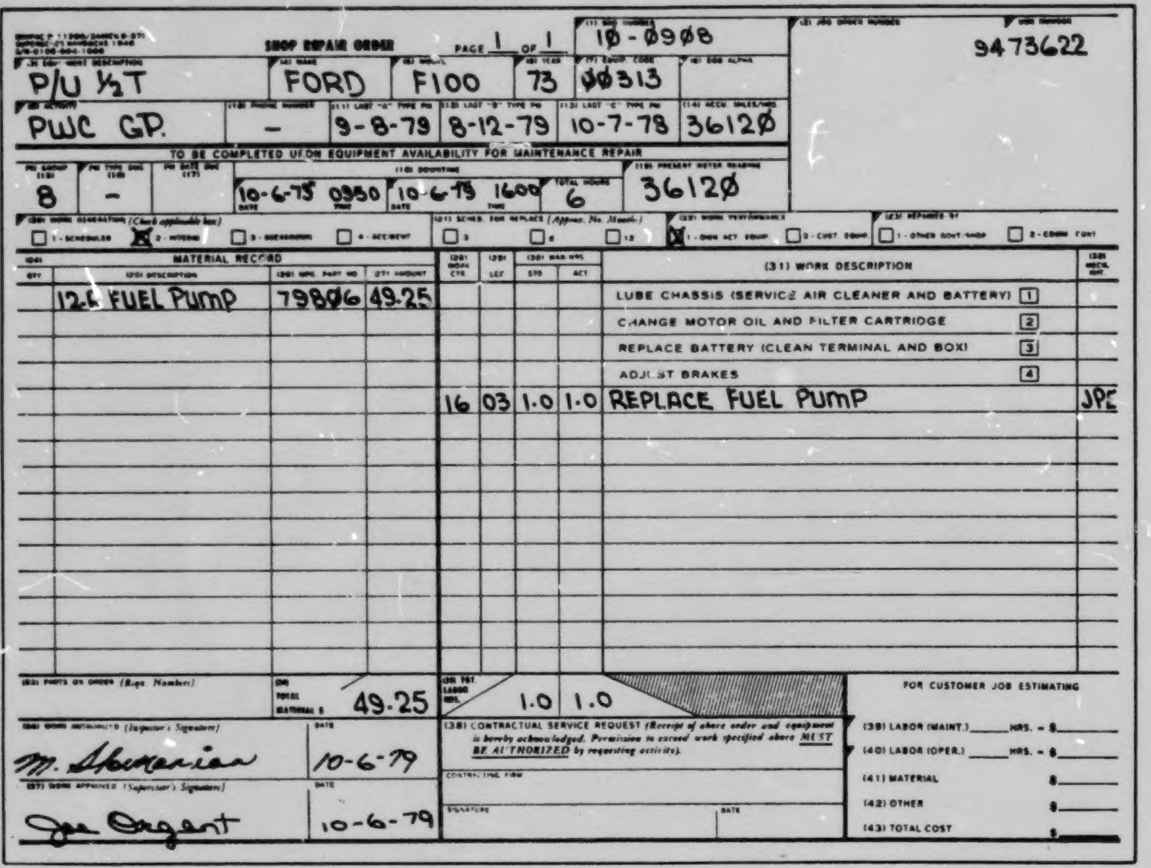
ASSIGNED TO	PHONE	TYPE OF ASSIGNMENT	EQUIP. CODE	JOB ORDER NO.	PM GROUP
NMCB 133		P-25	4850		7
MAKE	**MODEL**	**TYPE**	**YEAR**	**EST. ANNUAL MI/HRS**	**USN REG. NO.**
Tractor, Crawler	TD-20B	IHC	1969		48-00123

TYPE PM	DATE	CUMULATIVE MILEAGE OR HRS. OPN.	MILES (OR HRS) SINCE LAST PM	MILES (OR HRS) REPORTED FOR 6 MO. PERIOD	TYPE PM	DATE	CUMULATIVE MILEAGE OR HRS. OPN.	MILES (OR HRS) SINCE LAST PM	MILES (OR HRS) REPORTED FOR 6 MO. PERIOD
LAST A	2-4-74	1949	ENTRIES TRANSFERRED FROM PRIOR RECORD	▨					
LAST B	6-5-74	2259							
LAST C	4-1-74	2060							
A	8-7-74	2371	O/C						
B	10-1-74	2480	O/C, O/F						

VEHICLE/CONSTRUCTION EQUIPMENT PM RECORD NAVFAC 11240/9 (3-75) Supersedes NAVDOCKS 1949
S/N 0105-LF-[illegible]

2.10

Figure 12-4.—PM Record Card, NAVDOCKS 1949.



SHOP REPAIR ORDER PAGE 1 OF 1

10-0908

9473622

P/U ½T | FORD | F100 | 73 | 00313

PWC GP. | – | 9-8-79 | 8-12-79 | 10-7-78 | 36120

TO BE COMPLETED UPON EQUIPMENT AVAILABILITY FOR MAINTENANCE REPAIR

8 | – | | 10-6-79 0950 | 10-6-79 1600 | TOTAL HOURS 6 | 36120

☐ 1 ☒ 2 ☐ 3 ☐ 4 | ☐ 3 ☐ 6 ☐ 12 | ☒ 1 ☐ 2 | ☐ 1 ☐ 2

MATERIAL RECORD

								(31) WORK DESCRIPTION	
	12-V FUEL PUMP	79806	49.25					LUBE CHASSIS (SERVICE AIR CLEANER AND BATTERY) 1	
								CHANGE MOTOR OIL AND FILTER CARTRIDGE 2	
								REPLACE BATTERY (CLEAN TERMINAL AND BOX) 3	
								ADJUST BRAKES 4	
				16	03	1.0	1.0	REPLACE FUEL PUMP	JPE

TOTAL MATERIAL $ 49.25 | 1.0 | 1.0

M. Akmarian | 10-6-79

Joe Sargent | 10-6-79

(38) CONTRACTUAL SERVICE REQUEST (Receipt of above order and equipment is hereby acknowledged. Permission to exceed work specified above MUST BE AUTHORIZED by requesting activity).

FOR CUSTOMER JOB ESTIMATING

(39) LABOR (MAINT.) ______ HRS. = $______

(40) LABOR (OPER.) ______ HRS. = $______

(41) MATERIAL $______

(42) OTHER $______

(43) TOTAL COST $______

2.8.1

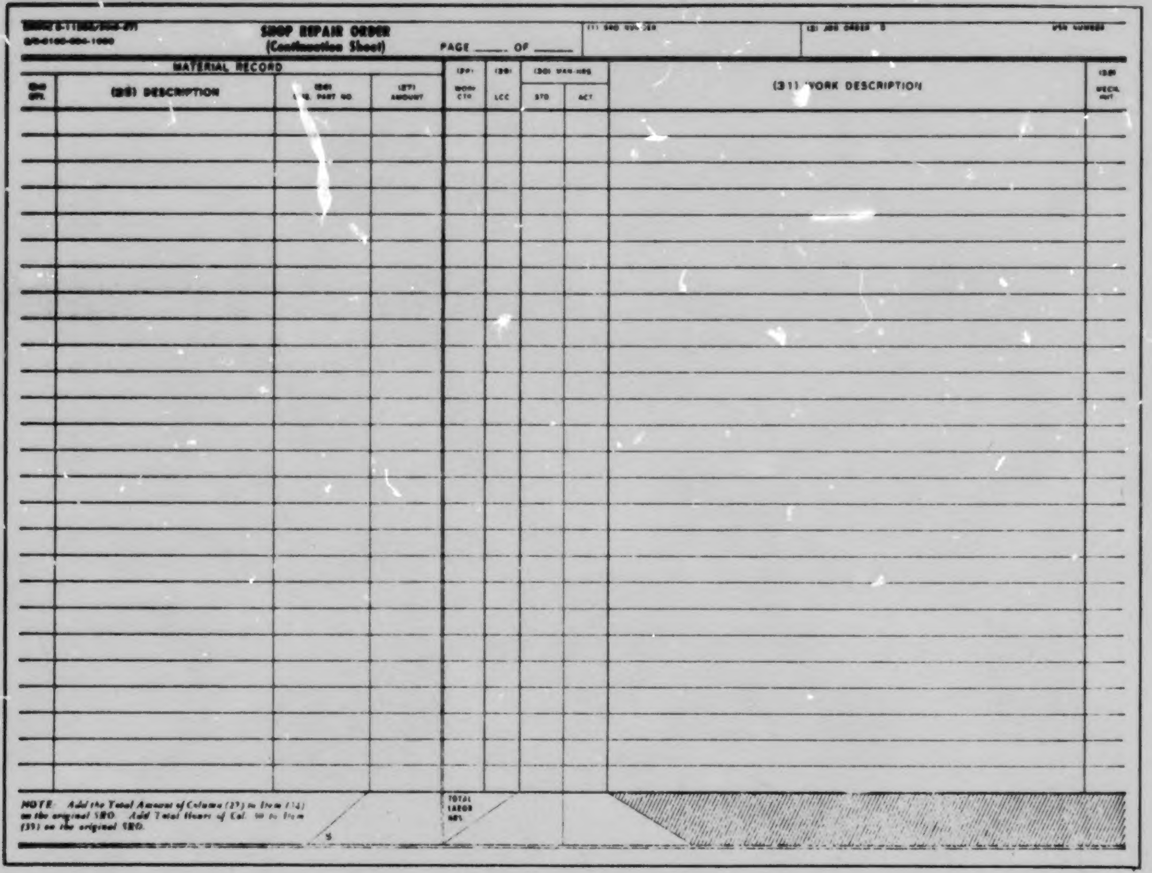
Figure 12-5.—Shop Repair Order (SRO).

three-part snapout set. It is required each time labor in excess of 0.3 hr or material is expended on a piece of USN-numbered equipment. Instructions for using the SRO are contained in the NAVFAC P-300 manual.

Equipment Repair Orders

The Equipment Repair Order (ERO) (fig. 12-7 and 12-8) was designed for use by all SEABEE units. The ERO is the sole authority to perform work on CESE, regardless of the location of the equipment, in the field or in the shop. An ERO is prepared by the unit for each piece of equipment every time labor or materials are expended on any of the types of work listed below:

1. Type "A" Preventive Maintenance
2. Type "B" Preventive Maintenance
3. Type "C" Preventive Maintenance
4. Receipt inspections (acceptance and BEEP's)
5. Deadline cycling or preservation of equipment
6. Repairs performed in the field (interim)



SHOP REPAIR ORDER
(Continuation Sheet) PAGE ___ OF ___

MATERIAL RECORD

(31) WORK DESCRIPTION

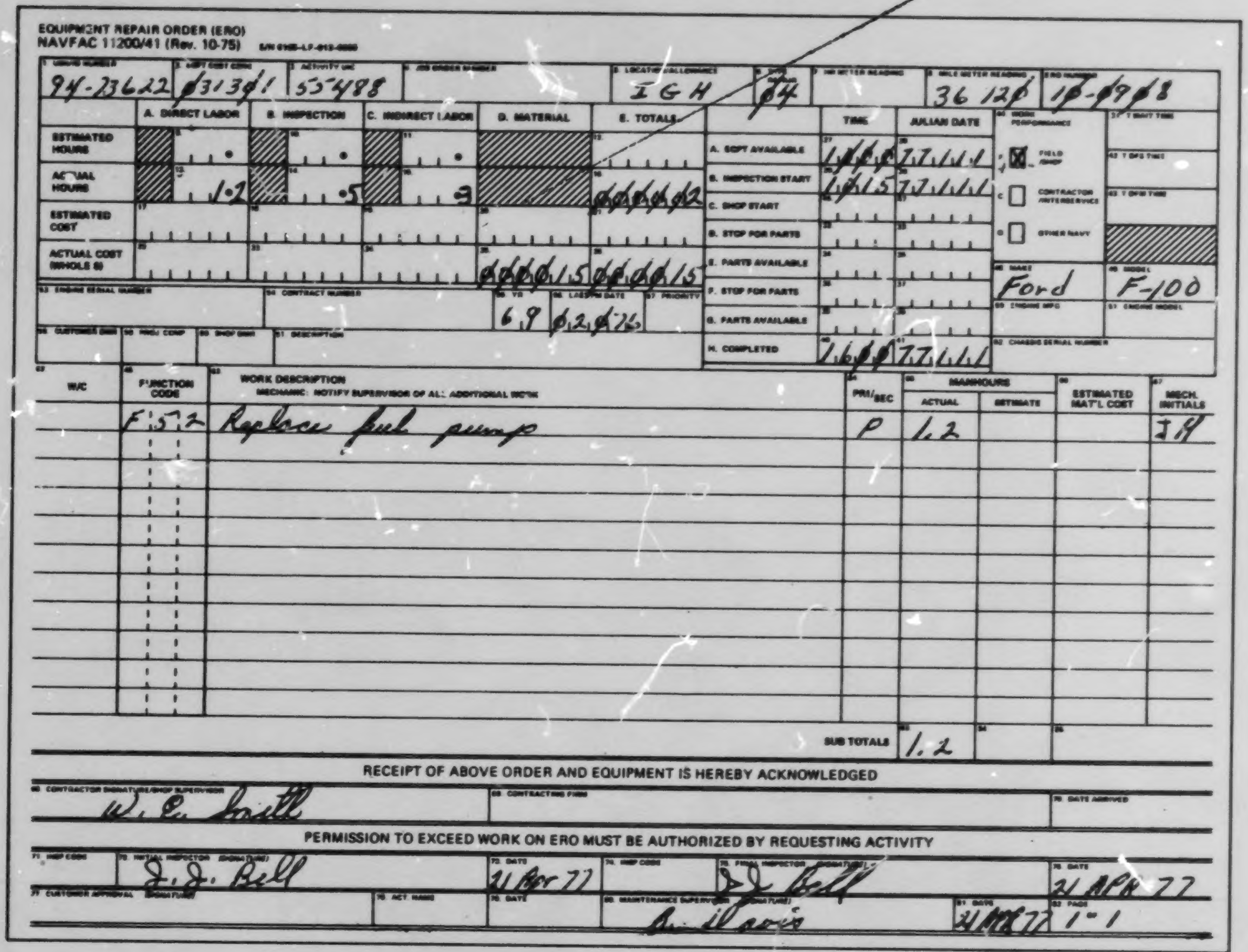
2.8.2

Figure 12-6.—Shop Repair Order continuation sheet.

7. Repairs performed because of a driver's report (interim)
8. Warranty
9. Rework
10. Accident

Every week NCF units forward all completed white copies of ERO's to the Naval Facilities Engineering Command, Facilities System Office (FACSO). FACSO extracts and compiles information contained in the heavily outlined blocks of the ERO (fig. 12-7). For this reason the accuracy and completeness of the information in these sections cannot be overstressed. FACSO uses this information to produce the Field Maintenance Report (FMR). This monthly report provides the maintenance supervisor with a detailed overview of how his shops are performing. ERO's containing incomplete or incorrect entries in the heavily outlined blocks are rejected. CESO maintenance division monitors rejected ERO's to insure that they are resubmitted. Complete instructions on the use of ERO's can be found in the *NCF Equipment Management Manual*, P-404.

Control of ERO's is required to prevent having two or three ERO's open for the same piece of equipment. Figure 12-9 shows a sample of an ERO log. Your activity may use a variation



EQUIPMENT REPAIR ORDER (ERO)
NAVFAC 11200/41 (Rev. 10-75)

94-23622	031301	55488		IGH	04		36 120	10-0908

	A. DIRECT LABOR	B. INSPECTION	C. INDIRECT LABOR	D. MATERIAL	E. TOTALS
ESTIMATED HOURS				▨	
ACTUAL HOURS	1.2	.5	.3	▨	000002
ESTIMATED COST					
ACTUAL COST (WHOLE $)				000015	000015

	TIME	JULIAN DATE
A. EQPT AVAILABLE	1000	77111
B. INSPECTION START	1015	77111
C. SHOP START		
D. STOP FOR PARTS		
E. PARTS AVAILABLE		
F. STOP FOR PARTS		
G. PARTS AVAILABLE		
H. COMPLETED	1600	77111

☒ FIELD SHOP
☐ CONTRACTOR INTERSERVICE
☐ OTHER NAVY

YR: 69
LAST PM DATE: 02076

MAKE: Ford
MODEL: F-100

W/C	FUNCTION CODE	WORK DESCRIPTION MECHANIC: NOTIFY SUPERVISOR OF ALL ADDITIONAL WORK	PRI/SEC	MANHOURS ACTUAL	MANHOURS ESTIMATE	ESTIMATED MAT'L COST	MECH. INITIALS
	F52	Replace fuel pump	P	1.2			JH
		SUB TOTALS		1.2			

RECEIPT OF ABOVE ORDER AND EQUIPMENT IS HEREBY ACKNOWLEDGED

W. E. Smith

PERMISSION TO EXCEED WORK ON ERO MUST BE AUTHORIZED BY REQUESTING ACTIVITY

J. J. Bell — 21 Apr 77
J J Bell — 21 APR 77
21 APR 77 — 1-1

2.400

Figure 12-7.—Equipment Repair Order (ERO) NAVFAC 11200/41 (front).

TYPE REPAIR (BLOCK 6)

01	A PM
02	B PM
03	C PM
04	Interim Repair
05	Overhaul
06	Breakdown (Field Repair)
07	Acceptance
08	Repair for Stock
09	Preservation and Storage Maintenance
10	Warranty
11	Rework
12	Accident
13	Shipping Inspection (CED)
14	Surveillance Inspection (CED)
15	Operational Test (CED)

FUNCTIONAL CODES (BLOCK 45)
SERVICES

01X	Lubrication
20X	Drain & Refill Engine Oil
03X	Engine Oil Filter
23X	Change Oil & Filters (Both 20X and 03X)
04X	Fuel Filters and Screens
50X	Drain & Refill Transmission Oil
06X	Transmission Filters
56X	Change Oil & Filters (Both 50X and 06X)
70X	Drain & Refill Hydraulic Oil
08X	Hydraulic Filters & Screens
78X	Change Oil & Filters (Both 70X and 08X)
09X	Drain & Refill Differential/Final Drive Oil/Filters
10X	Air Cleaner/Filter
11X	Battery Service/Recharge
12X	Cleaning
13X	Preservation
14X	Other

ATTACHMENTS

A01	Winch/PCU
A02	Backhoe
A03	Boom
A04	Buckets/Blades/Edges
A05	Sheeves/Pulleys/Wire Rope
A06	Augers
A07	Other

BRAKES

B09	Linings/Disks/Plates/Bands
B10	Drums/Rotors
B11	Backing Plate/Cams/Calipers
B12	Hoses/Lines/Pipes/Fittings
B13	Master/Wheel Cylinder
B14	Chambers/Diaphragms
B15	Hydrovac/Vacuum Pump
B16	Valves, Governors, Tank
B17	Parking/Hand Brake
B18	Other

SUSPENSION

C20	Springs
C21	Shock Absorbers
C22	Bars/Rods
C23	Other

DRIVE TRAIN

D25	Clutch, Main Drive
D26	Clutch, Control/Drum
D27	Manual Transmission
D28	Auto/Power Shift Transmission
D29	Auxiliary Transmisison
D30	Transfer Cases/Power Dividers
D31	Drive Shafts/U-Joints
D32	Differentials
D33	Drive Axles
D34	Final Drive/Planetaries
D35	Power Take-Off
D36	Drive Belts/Chains
D37	Torque Converter
D38	Other

ENGINE

E40	Engine Assy, Gas
E41	Engine Assy, Diesel
E42	Engine Assy, Aux
E43	Air Intake System
E44	Blowers/Superchargers/TurboChargers
E45	Exhaust System
E46	Emission Control System
E49	Cooling System
E50	Other

FUEL

F52	Fuel System
F53	Fuel Transfer Pump
F54	Fuel Injection Pump
F55	Injectors/Nozzles
F56	Carburetor
F57	Gov/Throttle Controls
F58	Other

HYDRAULIC

H60	Pump
H61	Pressure Control Valves
H62	Operating Valves
H63	Cylinders
H64	Motors
H65	Hoses/Lines/Pipes/Fittings
H66	Accumulators/Tanks
H67	Other

ELECTRICAL

J69	Replace Battery
J70	Replace Speedometer/Hourmeter
J71	Charging System
J72	Cranking System
J73	Lighting/Wiring System
J74	Electrical Controls/Panels
J75	Ignition System
J76	Instruments/Gages
J77	Generators, Power/Welding
J78	Electric Drive Motors
J79	Electronic Circuits
J80	Other

BODY AND FRAME

K82	Cab/Sheet Metal
K83	Body/Bed
K84	Cushions/Seats/Canvas/Bows/Sideracks
K85	Painting/Marking
K86	Frame/Mast
K87	Bumper/Guard/Lifting Device
K88	Fifth Wheel/Trlr Hitch/Towing Hook
K89	Outriggers/Landing Gear
K90	Other

STEERING SYSTEM

N92	Adjustments/Wheel/Alignment
N93	Steering Wheel/Box
N94	Steering Brakes/Clutches
N95	Linkages/Tie Rods/Etc.
N96	Ball Joints/King Pins
N97	Power Steering Pump/Belt
N98	Steering Cylinder/Hoses
N99	Other

PNEUMATIC

P01	Cylinders
P02	Compressors
P03	Separators/Filters
P04	Drifters
P05	Motors
P06	Hoses/Lines/Pipes/Fittings
P07	Controls
P08	Receivers/Oilers
P09	Other

SAFETY EQUIPMENT

S11	Fire Extinquisher
S12	Mirrors/Reflectors
S13	Windshield Wipers
S14	Mud Flaps/Guards/Shields
S15	Glass/Windshield
S16	Horn
S17	Other

PRODUCT TRANSFER

T19	Asphalt Pump
T20	Water/Mud Pump
T21	Refueling Pump
T22	Concrete Pump
T23	Conveyor Belt/Bucket/Screw
T24	Other

HEATER/VENTILATING SYSTEM

V2	Asphalt/Tank Heater
V27	Water Heater/Defroster
V28	Aggregate Heater
V29	Screed Heater
V30	Air Conditioning
V31	Other

WHEELS/TRACKS

W33	Wheels/Rims
W34	Tires/Tubes
W35	Bearings/Seals/Packings
W36	Hub Assy/Studs/Nuts
W37	Rollers/Idlers/Sprockets
W38	Track Frame/Guards
W39	Rails/Pins/Grousers
W40	Track Adjuster/Accumulator
W41	Other

PRODUCTION EQUIPMENT

Z43	Jaws/Hammer Mills
Z44	Rolls/Liners/Concaves
Z45	Screens
Z46	Mixers
Z47	Dryers
Z48	Screed
Z49	Scales/Meters
Z50	Collector
Z51	Other

Figure 12-8.—Equipment Repair Order (ERO) NAVFAC 11200/41 (back).

ERO Number	ECC	USN Number	Type ERO				Date In	Date Out	Remarks
			INT	A	B	C			
10-0301	252021	25-01297	X				4/3/77	4/8/77	
10-0302	030701	94-23465		X			4/3/77	4/3/77	
—	—	—							
—	—	—							
10-0308	031301	94-73622	X				4/21/77	4/21/77	Fuel Pump

81.581

Figure 12-9.—Sample ERO log.

of this log but it should contain the same basic information. The types of information generally called for are:

1. ERO number (locally assigned six-digit number. The first two digits denote the month of the year; the last four digits assign jobs in sequence, starting with number 0001.)
2. Equipment cost code
3. USN number
4. Type ERO (type of maintenance performed)
5. Date in (date ERO forwarded to inspector)
6. Date out (date ERO returned, work completed)
7. Remarks (date deadlined and so on)

This log is normally maintained by the PM clerk.

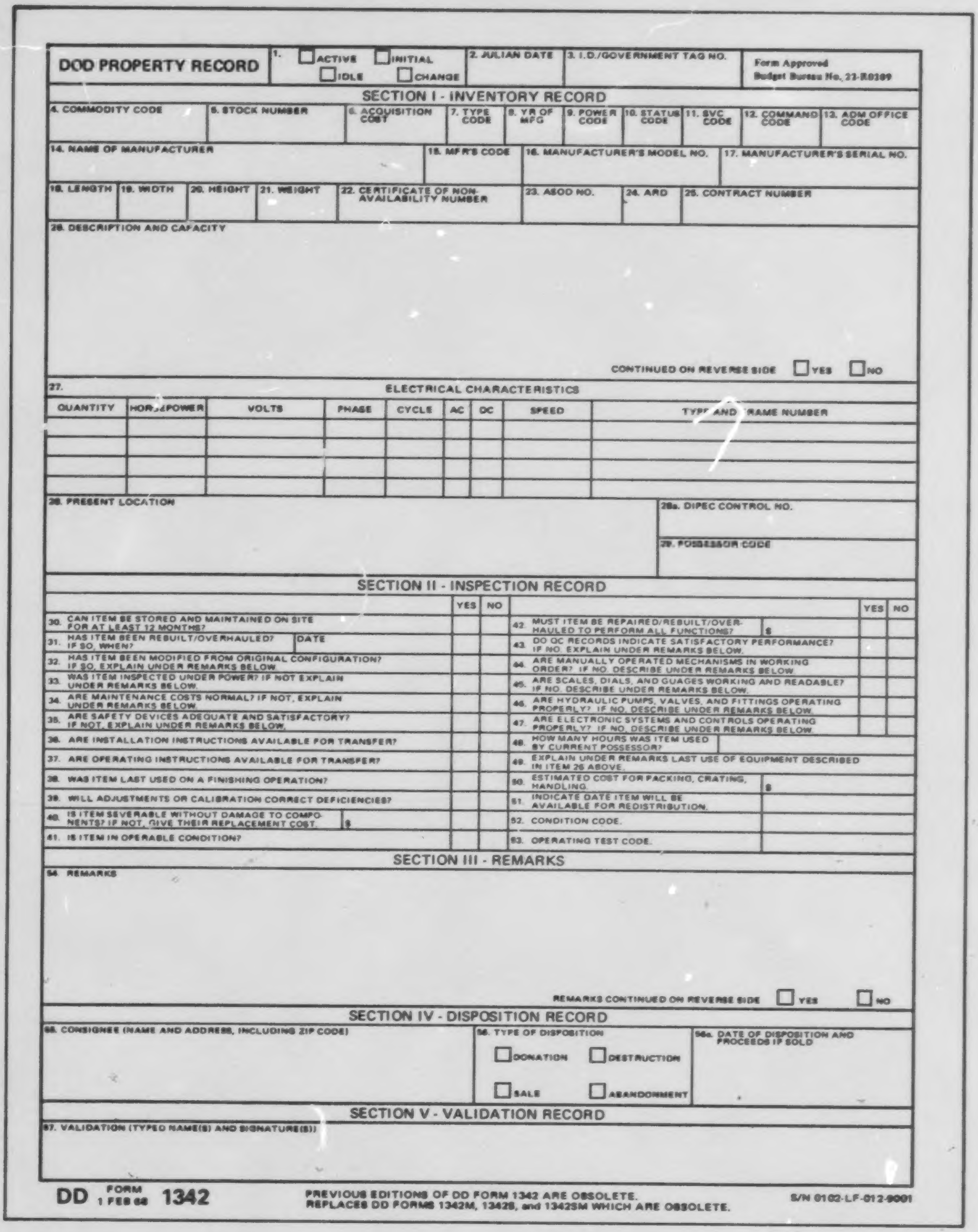
EQUIPMENT HISTORY JACKETS

An equipment history jacket is maintained for each USN-numbered item of CESE. The history jacket contains the vehicle's pertinent descriptive data and maintenance history. The descriptive data includes the appropriate DOD Property Record, DD Form 1342 (fig. 12-10) and Equipment Attachment Registration Records, NAVFAC 6-11200/45 (fig. 12-11), if applicable. The maintenance history jacket also includes the completed PM record cards and yellow copies of completed ERO's.

Periodically, each history jacket should be purified by reviewing all repair orders and discarding those of a minor inexpensive nature that have been retained a minimum of 90 days. ERO's relating to acceptance checks, "C" PM's, accidents, speedometer/hour meter replacement, and major repairs are retained in the history jacket for the life of the equipment. When a vehicle is transferred, the PM record card is removed from the PM group file and returned to the history jacket. The jacket is then either hand-carried or forwarded by certified mail to the receiving custodian. When a vehicle is transferred to a Property Disposal Office, the history jacket accompanies it.

MAINTENANCE ORGANIZATION

The organization of an equipment maintenance section varies depending upon several factors, including: number and type of assigned equipment, number and experience of personnel, work hours, number of shifts, environmental conditions, and the activity's mission. The organization we will discuss is based upon a typical Naval Mobile Construction Battalion operation, but the functions are equally applicable to small activities where one person may be required to perform several functions.



DOD PROPERTY RECORD

1. ☐ ACTIVE ☐ INITIAL ☐ IDLE ☐ CHANGE

2. JULIAN DATE

3. I.D./GOVERNMENT TAG NO.

Form Approved
Budget Bureau No. 22-R0309

SECTION I - INVENTORY RECORD

4. COMMODITY CODE	5. STOCK NUMBER	6. ACQUISITION COST	7. TYPE CODE	8. YR OF MFG	9. POWER CODE	10. STATUS CODE	11. SVC CODE	12. COMMAND CODE	13. ADM OFFICE CODE	

14. NAME OF MANUFACTURER	15. MFR'S CODE	16. MANUFACTURER'S MODEL NO.	17. MANUFACTURER'S SERIAL NO.

18. LENGTH	19. WIDTH	20. HEIGHT	21. WEIGHT	22. CERTIFICATE OF NON-AVAILABILITY NUMBER	23. ASOD NO.	24. ARD	25. CONTRACT NUMBER

26. DESCRIPTION AND CAPACITY

CONTINUED ON REVERSE SIDE ☐ YES ☐ NO

27. ELECTRICAL CHARACTERISTICS

QUANTITY	HORSEPOWER	VOLTS	PHASE	CYCLE	AC	DC	SPEED	TYPE AND FRAME NUMBER

28. PRESENT LOCATION

28a. DIPEC CONTROL NO.

29. POSSESSOR CODE

SECTION II - INSPECTION RECORD

		YES	NO
30.	CAN ITEM BE STORED AND MAINTAINED ON SITE FOR AT LEAST 12 MONTHS?		
31.	HAS ITEM BEEN REBUILT/OVERHAULED? IF SO, WHEN? DATE		
32.	HAS ITEM BEEN MODIFIED FROM ORIGINAL CONFIGURATION? IF SO, EXPLAIN UNDER REMARKS BELOW.		
33.	WAS ITEM INSPECTED UNDER POWER? IF NOT EXPLAIN UNDER REMARKS BELOW.		
34.	ARE MAINTENANCE COSTS NORMAL? IF NOT, EXPLAIN UNDER REMARKS BELOW.		
35.	ARE SAFETY DEVICES ADEQUATE AND SATISFACTORY? IF NOT, EXPLAIN UNDER REMARKS BELOW.		
36.	ARE INSTALLATION INSTRUCTIONS AVAILABLE FOR TRANSFER?		
37.	ARE OPERATING INSTRUCTIONS AVAILABLE FOR TRANSFER?		
38.	WAS ITEM LAST USED ON A FINISHING OPERATION?		
39.	WILL ADJUSTMENTS OR CALIBRATION CORRECT DEFICIENCIES?		
40.	IS ITEM SEVERABLE WITHOUT DAMAGE TO COMPONENTS? IF NOT, GIVE THEIR REPLACEMENT COST. $		
41.	IS ITEM IN OPERABLE CONDITION?		

			YES	NO
42.	MUST ITEM BE REPAIRED/REBUILT/OVERHAULED TO PERFORM ALL FUNCTIONS?	$		
43.	DO QC RECORDS INDICATE SATISFACTORY PERFORMANCE? IF NO, EXPLAIN UNDER REMARKS BELOW.			
44.	ARE MANUALLY OPERATED MECHANISMS IN WORKING ORDER? IF NO, DESCRIBE UNDER REMARKS BELOW.			
45.	ARE SCALES, DIALS, AND GUAGES WORKING AND READABLE? IF NO, DESCRIBE UNDER REMARKS BELOW.			
46.	ARE HYDRAULIC PUMPS, VALVES, AND FITTINGS OPERATING PROPERLY? IF NO, DESCRIBE UNDER REMARKS BELOW.			
47.	ARE ELECTRONIC SYSTEMS AND CONTROLS OPERATING PROPERLY? IF NO, DESCRIBE UNDER REMARKS BELOW.			
48.	HOW MANY HOURS WAS ITEM USED BY CURRENT POSSESSOR?			
49.	EXPLAIN UNDER REMARKS LAST USE OF EQUIPMENT DESCRIBED IN ITEM 26 ABOVE.			
50.	ESTIMATED COST FOR PACKING, CRATING, HANDLING.	$		
51.	INDICATE DATE ITEM WILL BE AVAILABLE FOR REDISTRIBUTION.			
52.	CONDITION CODE.			
53.	OPERATING TEST CODE.			

SECTION III - REMARKS

54. REMARKS

REMARKS CONTINUED ON REVERSE SIDE ☐ YES ☐ NO

SECTION IV - DISPOSITION RECORD

55. CONSIGNEE (NAME AND ADDRESS, INCLUDING ZIP CODE)

56. TYPE OF DISPOSITION
☐ DONATION ☐ DESTRUCTION
☐ SALE ☐ ABANDONMENT

56a. DATE OF DISPOSITION AND PROCEEDS IF SOLD

SECTION V - VALIDATION RECORD

57. VALIDATION (TYPED NAME(S) AND SIGNATURE(S))

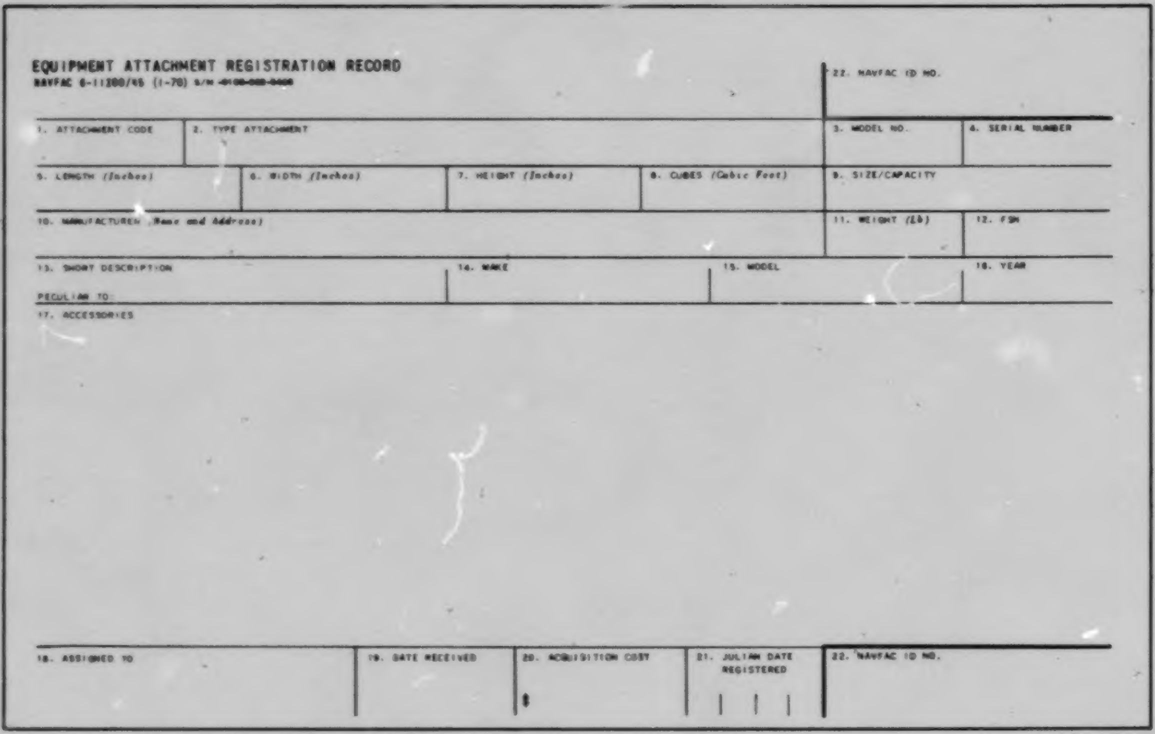
DD FORM 1 FEB 68 1342

PREVIOUS EDITIONS OF DD FORM 1342 ARE OBSOLETE.
REPLACES DD FORMS 1342M, 1342S, and 1342SM WHICH ARE OBSOLETE.

S/N 0102-LF-012-9001

Figure 12-10.—DOD Property Record, DD 1342.

81.582



EQUIPMENT ATTACHMENT REGISTRATION RECORD
NAVFAC 6-11200/45 (1-70) S/N [illegible]

22. NAVFAC ID NO.

1. ATTACHMENT CODE	2. TYPE ATTACHMENT		3. MODEL NO.	4. SERIAL NUMBER
5. LENGTH *(Inches)*	6. WIDTH *(Inches)*	7. HEIGHT *(Inches)*	8. CUBES *(Cubic Feet)*	9. SIZE/CAPACITY
10. MANUFACTURER *(Name and Address)*			11. WEIGHT *(Lb)*	12. FSN
13. SHORT DESCRIPTION PECULIAR TO:	14. MAKE	15. MODEL		16. YEAR
17. ACCESSORIES				
18. ASSIGNED TO	19. DATE RECEIVED	20. ACQUISITION COST $	21. JULIAN DATE REGISTERED	22. NAVFAC ID NO.

81.583

Figure 12-11.–Equipment Attachment Registration Record, NAVFAC 6-11200/45.

Maintenance Supervisor

The maintenance supervisor is normally the senior mechanic assigned to an activity. The maintenance supervisor is responsible for the entire maintenance program for all assigned CESE. One duty is to oversee the shop supervisors, inspectors, PM and cost control clerks, technical librarian and parts expediters. Additional responsibilities include:

1. Enforcing all established maintenance policies established by higher authority.
2. Approving all repair actions prior to start of work.
3. Approving all requisitions for the procurement of material. (May be delegated to shop supervisors).
4. Controlling all CESE transfers and disposals.
5. Supervising the Preventive Maintenance program.
6. Controlling all maintenance shop tools and kits.

Shop Supervisors

The typical NMCB maintenance organization is divided into three shops: Automotive (Auto or Light) Shop, Construction Equipment (Heavy) Shop, and Support Shop. Each shop is supervised by a shop supervisor, who is responsible for the mechanics and the quality of maintenance and repairs performed within the shop. As the title implies, the auto shop is responsible for automotive type CESE and small Materials-Handling Equipment (MHE). Occasionally, the auto shop may work on transit mixers, water/asphalt distributors, and 5000 series equipment. (The 5000 series equipment has an Equipment Cost Code and USN number starting with the digit "5"). The heavy shop is responsible for large MHE and construction equipment. Additionally, the heavy shop supervisor normally acts as the field maintenance supervisor. The support shops consist of all the separate supporting facilities, such as: machine shop, tire shop, steel (welding/body) shop, battery (electrical) shop, injection shop, and occasionally, lubrication facilities and the 5000 shop.

Crew Leader

The crew leader makes sure the job gets done. When assigned a job, the crew leader must figure out which member of the crew will do the work, the tools and repair parts required, what special safety precautions must be observed, and the priority of the job. Once a job is assigned, it's the crew leader's "baby". The crew leader is also responsible for insuring that the crew's time is reported, that all materials used on the job are recorded and that any additional repairs that may be required are reported to the supervisor.

Inspectors

Inspectors physically examine the equipment and determine the repairs and type of services required. They normally work directly for maintenance supervisors, and are directly responsible to them. It is important that the inspectors be mechanics who are extremely knowledgeable and proficient in their rating. The inspectors must be able to clearly and concisely describe each required repair action on the ERO's. It is of the utmost importance that all required work be listed. After all repairs have been completed, inspectors will normally inspect each piece of equipment to insure that the work was correctly accomplished. Comprehensive final inspections will greatly reduce equipment being returned to the shop for rework, increase equipment reliability, and in turn reduce the mechanic's workload. Inspectors may perform some minor repair work, which is normally very limited and pertains to inspection procedures only. Whenever suspected equipment abuse or recurring mechanical failures are discovered, inspectors should notify the maintenance supervisor immediately.

PM Clerk

PM clerks control the unit's Preventive Maintenance program as prescribed by the maintenance supervisor. They compile all CESE into PM groups, prepare the PM schedule, and maintain the PM record cards. They also initiate and control all ERO's, maintain the ERO log, the maintenance supervisor's shop workload file, and the equipment history jackets. At some activities the PM clerk is also responsible for maintaining the maintenance office equipment status boards.

Cost Control Clerk

Cost control clerks maintain the maintenance shop's repair parts status and accountability records. They provide liaison between the supply office and the shop. All requisitions for Not in Stock (NIS) and Not Carried (NC) material must pass through cost control clerks. They maintain the Direct Turnover (DTO) log and the repair parts summary sheets. Cost control clerks control the DTO parts storage bins, and maintain the deadline status board.

Technical Librarian

Technical librarians are responsible for the prepacked library which consists of operational, maintenance and parts manuals. They establish and enforce checkout procedures for the manuals, and initiate parts requisitions (NAVSUP 1250's). The task of researching and preparing the 1250's is normally handled by the technical librarian in order to free the floor mechanics from an administrative workload.

LABOR REPORTING

As a crew leader, you will be responsible for keeping a record of your crew's daily labor. Figure 12-12 shows the different subcategories of labor. Figure 12-13 shows one type of daily labor report form. These forms may vary from one activity to another, but the information is

PRODUCTIVE LABOR. Productive labor includes all labor that directly contributes to the accomplishment of the Naval Mobile Construction Battalion, including construction operations and readiness, disaster recovery operations, and training.

DIRECT LABOR. This category includes all labor expended directly on assigned construction tasks, either in the field or in the shop, and which contributes directly to the completion of the end product.

INDIRECT LABOR. This category comprises labor required to support construction operations, but which does not produce in itself. Indirect labor reporting codes are as follows:

X01 Construction Equipment Maintenance, Repair and Records
X02 Operation and Engineering
X03 Project Supervision
X04 Project Expediting (Shop Planners)
X05 Location Moving
X06 Project Material Support
X07 Tool and Spare Parts Issue
X08 Other

MILITARY OPERATIONS AND READINESS. This category comprises all manpower expended in actual military operations, unit embarkation, and planning and preparations necessary to insure unit military and mobility readiness. Reporting codes are as follows:

M01 Military Operations
M02 Military Security
M03 Embarkation
M04 Unit Movement
M05 Mobility Preparation
M06 Contingency
M07 Military Administrative Functions
M08 Mobility & Defense Exercise
M09 Other

DISASTER CONTROL OPERATIONS

D01 Disaster Control Operations
D02 Disaster Control Exercise

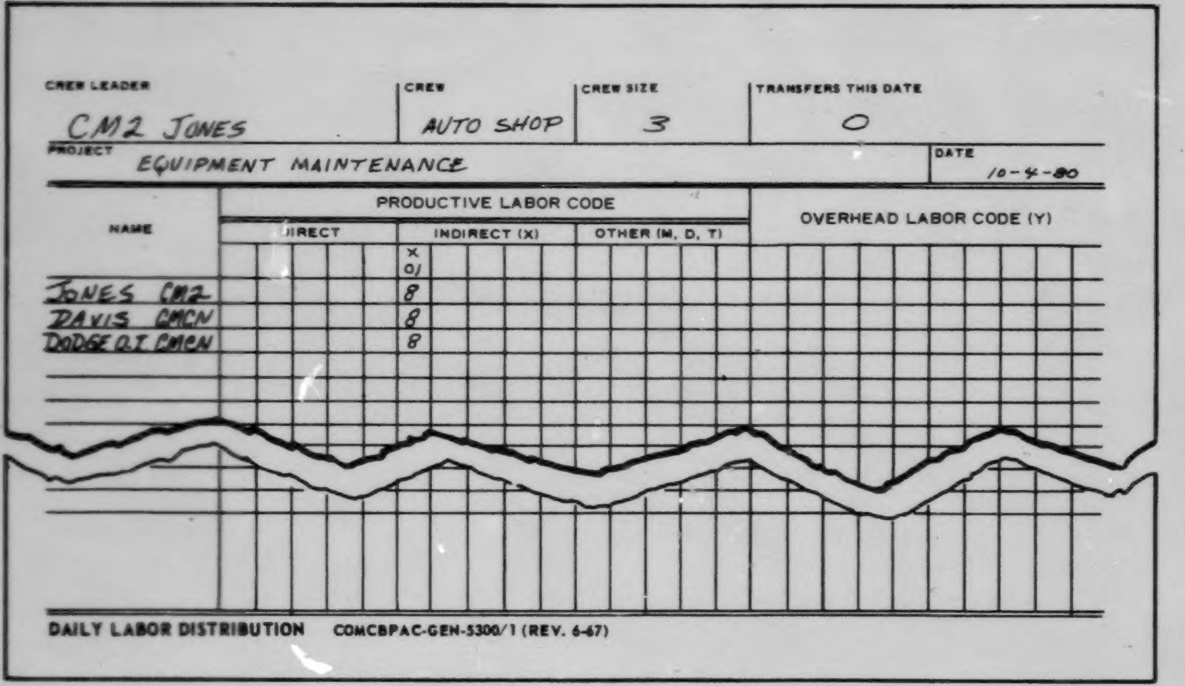
TRAINING. This category includes attendance at service schools, factory and industrial training courses, fleet type training, and short courses, military training, and organized training conducted within the battalion. Reporting codes are as follows:

T01 Technical Training
T02 Military Training
T03 Disaster Control Training
T04 Leadership Training
T05 Safety Training
T06 Training Administration

OVERHEAD LABOR. This category includes labor which must be performed regardless of whether a mission is assigned, and which does not contribute to the assigned mission. Reporting codes are as follows:

Y01 Administrative & Personnel
Y02 Medical & Dental Department
Y03 Navy Exchange and Special Services
Y04 Supply & Disbursing
Y05 Commissary
Y06 Camp Upkeep & Repairs
Y07 Security
Y08 Leave & Liberty
Y09 Sickcall, Dental & Hospitalization
Y10 Personal Affairs
Y11 Lost Time
Y12 TAD not for unit
Y13 Other

Figure 12-12.—Subcategories of labor. 133.417



CREW LEADER CM2 JONES

CREW AUTO SHOP

CREW SIZE 3

TRANSFERS THIS DATE 0

PROJECT EQUIPMENT MAINTENANCE

DATE 10-4-80

NAME	PRODUCTIVE LABOR CODE			OVERHEAD LABOR CODE (Y)
	DIRECT	INDIRECT (X)	OTHER (M, D, T)	
		X 01		
JONES CM2		8		
DAVIS CMCN		8		
DODGE O.T. CMCN		8		

DAILY LABOR DISTRIBUTION COMCBPAC-GEN-5300/1 (REV. 6-67)

54.309

Figure 12-13.—Daily labor distribution card.

basically the same. Nearly all mechanics' labor falls under indirect labor. One point to keep in mind is that only overhead labor does not contribute to productive labor. Time cards should always have a person's rate listed after the name in order to figure labor cost.

MAINTENANCE SUPPORT

The tools, consumables and spare parts needed to support your unit's equipment allowance are all portions of maintenance support. The supply department is responsible for providing these items.

In a battalion, the supply department is under the control of the senior supply officer who is assisted by a Chief Storekeeper. The supply section (S4) is responsible for general supply, ship service, material control, and delivery. The material control section is responsible for ordering, receiving, and controlling all tools, material and repair parts. So, you can see that S4 has a big job. Keep this in mind when you feel that they should drop everything just to wait on you.

REPAIR PARTS SUPPORT

All mechanics expect that repair parts will be available when needed and rightly so. It is the job of your unit's supply organization to make sure you get the parts you need. However, supply cannot satisfactorily perform its support mission without the help of maintenance personnel. Mechanics should understand the repair parts supply system and make sure that supply knows what you need and when you need it. Telling supply you need a "whatchamacallit" for a jeep will not get you anything, but give them the proper nomenclature and a good part number and they can get the part for you. Normally at least one mechanic will be assigned to the repair parts storeroom to provide technical information and assistance. The cost control clerk normally provides liaison with supply for checking requisition status. The maintenance supervisor will assist supply in determining additional repair parts requirements. The criteria established by the Chief of Naval Operations for initial parts support of new or like-new equipment is based on two 10-hour shifts, 7 days per week, for the first 90 days of operation.

Levels of Support

There are four different levels of repair parts support (O, G, H or D) that can be assigned to a unit, depending upon its mission, location, maintenance capabilities, and so on.

The "O" LEVEL support is designed for SEABEE teams, Construction Base units (CBU's), Reserve battalions and outlying NMCB's which normally perform only organizational level of maintenance. The "G" LEVEL support is designed for NMCB/PHIBCB major detachments that perform intermediate level maintenance. The "H" LEVEL support is designed for main bodies of NMCB/PHIBCB that perform intermediate level maintenance. The "D" LEVEL support is designed for major shops that perform depot level maintenance. Each level of support (except "O", of course) includes all lower level items; for example, "H" level includes all "O" and "G" level items.

Categories of Repair Parts

Repair parts can be divided into two categories: parts peculiar and parts common.

The REPAIR PARTS PECULIAR category is composed of parts which only fit a specific make and model piece of equipment. When a unit requests support for an allowance of equipment, CESO identifies the applicable Allowance Parts Lists (APL's) for each make and model of equipment in the allowance. Using the APL's that are identified by CESO, Ships Parts Control Center (SPCC) consolidates these APL's into a tailored repair parts list. This list is normally referred to as a Consolidated SEABEE Allowance List (COSAL) or a NAVSUP Modifier Code 98 (MOD 98 kit). CESO provides copies of the COSAL to both the requesting unit and the Construction Battalion Center (CBC) which supports it. The CBC is then responsible for drawing the required items from stock or initiating procurement action and shipping the parts to the unit which requested the allowance.

The REPAIR PARTS COMMON allowance is composed of common and consumable supplies that can be used on numerous types of equipment. These items have been separated into parts common assemblies (MOD 97 kit) to reduce redundancy and overstocking of these items that would occur if they were listed in each separate APL. Presently the MOD 97 kit consists of 22 individual kits, such as: hydraulic hose and fittings, nuts and bolts, electrical terminals and wire, "O" rings, and so on. MOD 97 kits are designed to supplement MOD 98 kits for the first 90 days or 1800 construction hours of a contingency operation. It must be remembered that MOD 97 kits are not designed to support a unit for a full deployment.

COSAL Arrangement

Each COSAL is arranged and divided into three separate parts. PART I consists of cross-reference lists which are used to determine which APL applies to which USN number. In addition, these lists contain equipment descriptions. Part I is composed of three separate cross-reference lists, each containing the same information, but sorted and printed in different sequences. Section A is printed in USN number sequence, Section B is in Equipment Cost Code (ECC) sequence, and section C in APL number sequence.

PART II consists of APL's which are the actual parts listings. The APL's are sorted and arranged in numerical sequence. Within each APL, the parts are arranged by Component Identification groups (CID's). Figure 12-14 shows the CID groups presently being utilized by the NCF. The first CID is always the allowance application group. The second group is the technical manual group which lists all the applicable operating, maintenance, and parts manuals. The remainder of the APL is the actual parts listing.

PART III consists of a Stock Number Sequence List (SNSL) and two repair parts cross-reference lists. The SNSL lists the repair parts, arranged in National Item Identification

CID	Group Name
000	Allowance Application Group (Gp)
0TM	Technical Manual Gp
001	Engine Gp
002	Truck Engine Gp
003	Starting Engine Gp
004	Auxiliary Engine Gp
005	Clutch Gp
006	Fuel System Gp
007	Exhaust System Gp
008	Cooling System Gp
009	Electrical System Gp
010	Transmission Gp
011	Auxiliary Transmission Gp
012	Power Transfer Gp
013	Propeller Shaft Gp
014	Front Axle Gp
015	Rear Axle Gp
016	Brakes Gp
017	Wheels Gp
018	Tracks Gp
019	Steering Gp
020	Frame Gp
021	Springs/Shock Absorbers Gp
022	Body, Cab, Hood, Hull Gp
023	Hoists Gp
024	Power Control Unit Gp
025	Power Take Off Gp
026	Miscellaneous Body Gp
027	Elevator Gp
028	Electric Motors Gp
029	Electric Generators Gp
030	Electrical Equipment Gp
031	Hydraulic Systems Gp
032	Air and Vacuum Systems Gp
033	Gage and Measuring Devices Gp
034	Pneumatic Equipment Gp
035	Pump Gp
036	Burner Gp
037	Mach Tools/Related Equip Gp
038	Snow Removal Equipment Gp
039	Mowing/Sweeping Equipment Gp
040	Servicing Equipment Gp
041	Concrete/Asphalt Equipment Gp
042	Crane/and/or Shovel Gp
043	Grader Gp
044	Dozer Gp
045	Ditcher or Trencher Gp
046	Road Roller Gp
047	Earth Auger Truck Mounted Gp
048	Conveying Equipment Gp
049	Crushing Equipment Gp
050	Screening/Washing Equip. Gp
051	Fire Fighting Equipment Gp
052	Refrigeration/Acng Gp
053	MMK Gp
054	Separator Gp
055	Running Gear Gp
056	Manifold Gp
057	Tank Gp
058	Trailer Gp
059	Flood Light Gp
060	Filter or Strainer Gp
061	Chlorine Control Gp
062	Evaporating Gp
063	Water Fording Gp
064	Machinery Gp
065	Laundry Equipment Gp
066	Winterization Gp
067	Bobsled Gp
068	Dolly Gp
069	Generator Lox & Nitrogen Gp
070	Steam Cleaning Gp
071	Spraying Equipment Gp
072	Saw Gp
073	Distillation Equipment Gp
074	Heater Gp (Gas or Fuel)
075	Blower Gp
076	Boiler Gp
077	Pile Driver Gp
078	Water Purification Gp
079	Reel Gp
080	Scraper Gp
081	Ripper Gp
082	Outboard Drive Gp
083	Rotary Tiller Soil Stabilizer Gp
085	Drill Equipment (Pneu) Gp
086	Dehydrator Gp
087	Remote Control Gp

Figure 12-14.—Component identification group numbers (CID's).

Number (NIIN) sequence, which were provided in the COSAL to support the assigned level of support. The SNSL also lists all the APL numbers each part is stocked for, the unit price, and the total COSAL quantity. The first list crosses manufacturer's part number to NSN. The second list crosses NSN, in NIIN sequence, to part number. Part III is not a master cross-reference; if the number you are researching is not included in the COSAL, it will not be in these lists.

Technical Manuals

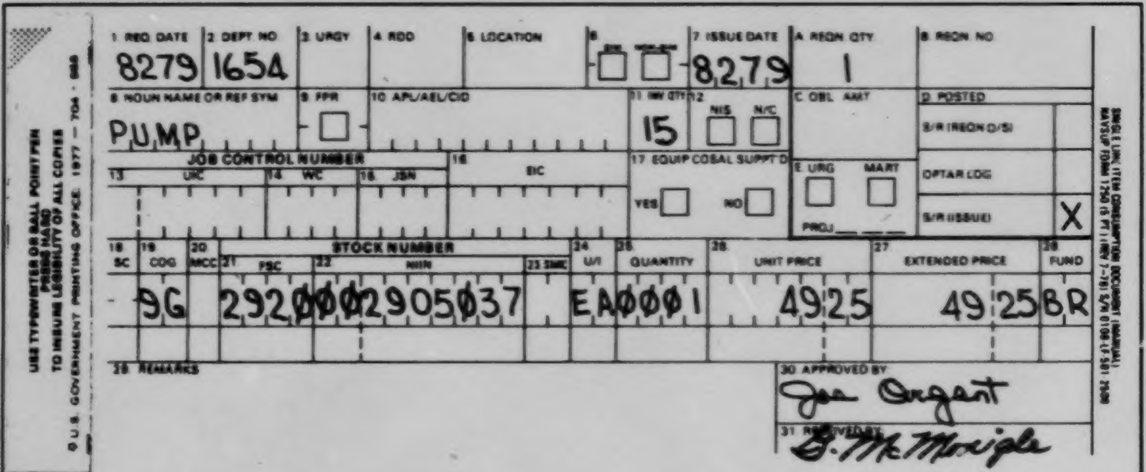
One key to any effective equipment maintenance program is the availability of authoritative technical data and guides for each unique item of equipment. Within the NCF, this information is supplied through the appropriate operator manuals, lubrication charts, parts manuals and shop repair manuals. These Technical Manuals (TM's) are included in each unit's parts peculiar COSAL. The quantity of TM's is determined by the same methods used for repair parts. In general, this results in the following number of TM's being provided: one copy for each piece of equipment of the same make and model assigned to the unit; two copies for two to four pieces of the same make and model; three copies for five to eight pieces of the same make and model; and four copies for more than eight of the same make and model equipment.

Maintenance of Manuals

All NCF units are responsible for maintaining, in good condition and in the proper quantities, all TM's listed in their COSAL. It is important for units to maintain inventory control of TM's through the use of periodic inventories, checkout procedures, and so on, as replacement manuals are normally hard to obtain. Manuals in excess of COSAL quantities must be returned to CBC, Port Hueneme, California. TM's that are lost, damaged, wornout, or otherwise unserviceable, may be replaced by submission of funded requisitions to the appropriate CBC.

REQUESTING SPARE PARTS

A NAVSUP Form 1250, Single Line Item Consumption/Management Document, is shown in figure 12-15. This form is used as authorization for drawing parts and requesting


USE TYPEWRITER OR BALL POINT PEN
PRESS HARD
TO INSURE LEGIBILITY OF ALL COPIES
U.S. GOVERNMENT PRINTING OFFICE: 1977 — 704 -

1 REQ DATE: 8279
2 DEPT NO: 1654
3 URGY:
4 RDD:
5 LOCATION:
6 ☐ ☐
7 ISSUE DATE: 8279
A REQN QTY: 1
B REQN NO:
8 NOUN NAME OR REF SYM: PUMP
9 FPR: ☐
10 APL/AEL/CID:
11 INV QTY: 15
12 NIS ☐ N/C ☐
C OBL AMT:
D POSTED
S/R (REQN O/S)
OPTAR LOG
S/R (ISSUE): X
JOB CONTROL NUMBER: 13 UIC, 14 WC, 15 JSN
16 EIC
17 EQUIP COSAL SUPPT'D: YES ☐ NO ☐
E URG ☐ MART ☐
PROJ ___ ___ ___

18 SC	19 COG	20 MCC	21 FSC (STOCK NUMBER)	22 NIIN (STOCK NUMBER)	23 SMIC (STOCK NUMBER)	24 U/I	25 QUANTITY	26 UNIT PRICE	27 EXTENDED PRICE	28 FUND
	9G		2920	002905037		EA	00001	49.25	49.25	BR

29 REMARKS:
30 APPROVED BY: Joe Organt
31 RECEIVED BY: G. McMonigle

SINGLE LINE ITEM CONSUMPTION DOCUMENT (MANUAL)
NAVSUP FORM 1250 (5 PT) (REV 7-78) S/N 0108-LF-581-7

17.84

Figure 12-15.—Single Line Item Consumption/Management Document, NAVSUP 1250.

requisition of Not In Stock (NIS) or Not Carried (NC) items from supply. The 1250 is a five-part snap set with copies colored white (original), green, red, yellow and buff (hard back). It is not a purchase document and does not leave the command. The form may be filled out with either a ballpoint pen or a typewriter. Confusion between the number zero and the letter "O" can be avoided by using the communication symbol (Ø) for zero. The 1250 must be signed by the maintenance supervisor or designated representative when requesting spare parts. Remember that when you request a part, it is your responsibility to insure that the right part is ordered. So, get the correct information on the 1250.

USING PART NUMBERS

In order for you to identify what part you need, you will have to use part numbers. There are two types of part numbers you will be concerned with: manufacturer's numbers and national stock numbers.

Manufacturer's Part Numbers

Manufacturer's part numbers are those used by the manufacturer of a piece of equipment to identify each part on that piece of equipment. These part numbers are usually a combination of letters and numbers or all numbers.

National Stock Numbers

Effective September, 1974, the United States agreed to replace its federal stock numbering system with a new 13-digit system which conforms to the NATO stock numbering format. This new system is known as the NATIONAL STOCK NUMBER (NSN) system. The 13-digit NSN is broken down into two major groups. The first 4 digits of the NSN is the Federal Supply Classification (FSC) which groups similar items into classes. The last 9 digits of the NSN is the National Item Identification Number (NIIN). The first 2 digits in the NIIN identifies the NATO country which cataloged the item, and the last 7 digits identifies the item.

As pointed out above, NSN numbers provide you with the federal class of the item (first 4 digits), what country cataloged the item (digits 5 and 6), and the item's identification number (last 7 digits).

Part III of the COSAL is the section used to cross-reference manufacturer's part numbers to NSN's.

REPAIR PARTS CONTROL

Each maintenance department is required to maintain control over spare parts. One of the biggest problems in some maintenance sections is the control of Direct Turnover (DTO) spare parts. DTO parts are those ordered for direct turnover to the user.

If the DTO parts records are to be complete and accurate, all NAVSUP 1250's for NIS and NC repair parts must pass through the cost control clerk before being submitted to the supply office. The supply office maintains current procurement and shipping status for all items on order. When requesting the status of a requisition from supply, cost control clerks must be able to identify, by requisition number, which procurement document they are interested in. Accurate DTO parts records accomplish this and allow the cost control clerk to identify the USN-numbered equipment each part was ordered for. The DTO repair parts status-keeping system which we will cover provides excellent accountability with a minimum of effort. This system consists of two separate records designed to be used together—the DTO log and the repair parts summary sheets. It is unimportant whether these records are kept in the form of a book, a looseleaf binder, on cards, or some other form.

DTO Log

The DTO log (fig. 12-16) is a record of all NIS and NC requisitions submitted to the unit supply. It is maintained in such a way that the last NAVSUP 1250 entered is the last parts request submitted to the supply office. This tells the cost control clerk when the requisitions were submitted to supply. Normally, supply should order priority "A" requisitions within 24 hours

418

Dept. No.	Julian Date	PMG	USN	NSN	Desc	Qty	PRI	Req. No.	Rec'd
0001	4003	01	48-00123	2815-739-6098	VALVE	1	13	4010-2111	
0002	4003	01	48-00123	2815-962-5622	SPRING	1	13	4010-2112	
0003	4010	06	96-11031	2910-950-8385	INJECTOR	6	06		

Figure 12-16.—Direct Turn Over (DTO) Log.

and priority "B" and "C" requisitions within 7 days. After accomplishing all ordering actions and issuing a procurement document, supply enters the requisition number in block B of the 1250 and returns the red copy to the cost control clerk. If the supply office seems to be taking excess time, the cost control clerk should request the status of the 1250. This should normally be an informal check to determine if the requisition or the 1250 red copy has been lost or misfiled. The DTO log will provide a cross index between the requisition number, the department order number, and the USN number. This cross-reference allows the cost control clerk to determine the appropriate USN number for which a part was ordered. This is invaluable for followup actions in the event of lost or misfiled requisitions, lost or missing shipping documents, partial or duplicate parts shipments, and so forth. The columns required to maintain an effective DTO log are listed and explained below:

Column (1)	Department Order Number—The internal control number assigned to each 1250 submitted to the unit supply, numbered in sequence starting with 0001. This column is maintained in such a way that the last 1250 entered is the last part ordered. The cost control clerk also enters the department order number in Block 2 of the 1250 before sending it to supply.
Column (2)	Julian Date—The date the 1250 was submitted to supply. This is also entered on the 1250 in Block 1. The Julian date is a four-digit number. The first digit indicates the year, and the last three digits indicate the day of the year. For example, February 10, 1978, would be written: 8041.
Column (3)	PM Group—The PM group that the appropriate USN number is assigned to.

NOTE: This information is obtainable elsewhere, most notably here because several sections of the DTO status-keeping system are arranged in PM group sequence, such as repair part summary sheets, preparation of PM ERO's, DTO parts storage bins, and so on.

Column (4)	USN Number—The USN registration number of the vehicle the part was ordered for, as shown in block 29 of the 1250.
Column (5)	NSN Number—The NSN part number of the ordered item as shown in block 21, 22 or block 29 of the 1250.
Column (6)	Description—Nomenclature or noun name of ordered item as shown in block 8 of the 1250.

Column (7) Quantity—How many were ordered, as shown in block 25 of the 1250. This entry is very helpful for identifying partial shipments.

Column (8) Priority—Urgency of need as shown in block 3 of the 1250.

Column (9) Requisition Number—Entered when the 1250 red copy is returned from supply with the requisition number entered in block B. All supply office documents are filed by this number.

Column (10) Received—Date the cost control clerk processed the paperwork showing that the ordered parts have been received from supply.

Repair Parts Summary Sheet

The repair parts summary sheet (fig. 12-17) shows all parts on order for each specific vehicle. One sheet is maintained for each USN number; the summary sheets are normally filed in PM group order. This is for the convenience of the cost control clerk, because the DTO parts bin and the PM ERO's are arranged in the same order. All PM ERO's pass through the cost control clerk to preclude the accidental reordering of items. This also allows the cost control clerk to attach notification to the ERO that parts have been received and are in the DTO bin. Summary sheets are used to verify if the part is still required and to indicate why the part was originally ordered. Summary sheets provide ready reference for determining the quantity of parts received from a multiple order (i.e., parts for an engine overhaul, deadlined vehicle, and so on). When equipment is transferred or disposed of, the summary sheet is used to identify any outstanding requisitions so that they may be canceled. The HEADING on each repair parts summary sheet must show the ECC and USN number.

The columns normally required on a repair parts summary sheet are listed and explained below:

Column (1) Julian Date—Date the 1250 was submitted to supply. This date is also entered on the 1250 in block 1.

Column (2) Department Order Number—The number entered in block 2 of 1250 prior to submittal to supply. This number serves as a cross index between the DTO log and the summary sheets.

CODE 4850 USN 48-00123

DATE	DEPT. NO.	REQ. NO	NOMENCLATURE	FOLLOW-UP			REC'D
1/18/72	0009	2021-2211	GASKET SET	1/31			2/28
8/7/72	0161	2230-2713	INJECTOR	8/28	9/15	10/2	10/11
12/12/72	0218		RAINCAP				

Figure 12-17.—Repair Parts Summary Sheet.

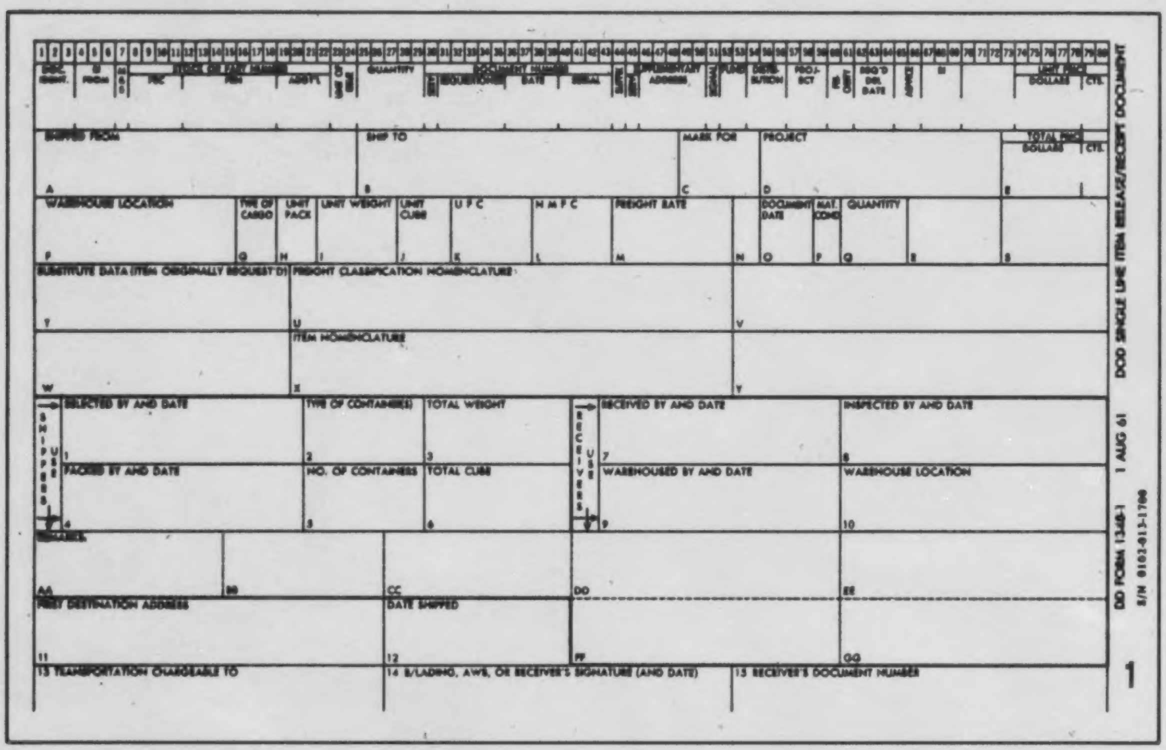
Column (3)	Requisition Number—Entered when the 1250 red copy is returned from supply with the requisition number entered in block B.
Column (4)	Nomenclature—Description or noun name of the ordered item as shown in block 8 of the 1250.
Column (5)	Followup—Dates that the cost control clerk requested the status from supply.
Column (6)	Received—Date showing when the receiving document for the ordered items was processed. This column should contain enough room to allow for explaining and cross-referencing cancellations, partial shipments, reorders, and so forth. ALWAYS enter the new department order number on all reorders.

The maintenance supervisor determines and assigns priorities for all 1250's marked NIS or NC, and completes blocks 3 and 4. The maintenance supervisor and/or higher authority must approve all 1250's for procurement by signing block 30. All 1250's for NIS or NC material must pass through the cost control clerk. The cost control clerk assigns and enters a department order number in block 2 of the 1250, in the DTO log, and on the repair parts summary sheet. The 1250's are then submitted to the unit supply, and the cost control clerk retains the yellow copies. These yellow copies are filed with the appropriate summary sheet. Supply then completes the ordering actions and issues a procurement document.

Each procurement document is assigned a requisition number, consisting of the Unit's Identification Code (UIC), four-digit Julian date and a four-digit serial number, by supply. Supply enters this requisition number in block B of the appropriate 1250 and returns the red copy to the cost control clerk. The cost control clerk enters the requisition number on both the DTO log and the summary sheet. The red copy of the 1250 is then filed in place of the yellow copy, which can then be thrown away. The cost control clerk keeps up-to-date on the status of all parts on order by frequently checking with supply. When supply receives an ordered repair part, it is identified by a DOD Single Line Item Release Receipt Document, DD 1348-1 (fig. 12-18). Once a part is received, supply will forward a copy of the DD Form 1348-1 to the cost control clerk. Because the 1348-1 does not normally contain the applicable USN number, the cost control clerk must match the requisition number with the DTO log to determine which USN number the part was ordered for. It must then be determined if the part is still required. Questionable items are discussed with the maintenance supervisor. Parts that are not required are not stored in the DTO bins; they are returned to supply for return to stock, return to a CBC, disposal, and so on, in accordance with supply regulations. The cost control clerk tags each required repair part with the correct USN number, PM group and the red 1250 copy. He ensures the DTO log and the summary sheet are dated, showing the item was received. The part is stored in the DTO bin and the 1348-1 is filed with the appropriate summary sheet. The summary sheet can then be used as a record showing what parts are stored in the DTO bins.

When a part is issued, a line is drawn through the received date (column 6) with a yellow marker pen showing the part is no longer in the bin. If the received part is for a deadlined piece of equipment, the maintenance supervisor is notified, and determines if enough parts are available to restart the work on the vehicle.

Each time an ERO is issued, the cost control clerk checks the repair parts summary sheets to determine if any parts are stored in the DTO bin for the USN concerned. If so, the 1348-1 is attached to the ERO to alert the shop supervisor. The shop supervisor insures that the parts are either utilized or returned to the unit supply. The DTO bin for the PM group that was worked through the shop yesterday should be empty today, as all parts should have been either



1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80

QUANTITY
DATE
DISTRI-BUTION
PROJ-ECT
REQ'D DEL. DATE
DOLLARS
CTS.

SHIPPED FROM A
SHIP TO B
MARK FOR C
PROJECT D
TOTAL PRICE DOLLARS CTS. E

WAREHOUSE LOCATION F
TYPE OF CARGO G
UNIT PACK H
UNIT WEIGHT I
UNIT CUBE J
U F C K
N M F C L
FREIGHT RATE M
N
DOCUMENT DATE O
MAT. COND P
QUANTITY Q
R
S

SUBSTITUTE DATA (ITEM ORIGINALLY REQUEST'D) T
FREIGHT CLASSIFICATION NOMENCLATURE U
V

W
ITEM NOMENCLATURE X
Y

SHIPPERS USE
SELECTED BY AND DATE 1
TYPE OF CONTAINER(S) 2
TOTAL WEIGHT 3
PACKED BY AND DATE 4
NO. OF CONTAINERS 5
TOTAL CUBE 6

RECEIVERS USE
RECEIVED BY AND DATE 7
INSPECTED BY AND DATE 8
WAREHOUSED BY AND DATE 9
WAREHOUSE LOCATION 10

REMARKS
AA
BB
CC
DD
EE

FIRST DESTINATION ADDRESS 11
DATE SHIPPED 12
FF
GG

13 TRANSPORTATION CHARGEABLE TO
14 B/LADING, AWB, OR RECEIVER'S SIGNATURE (AND DATE)
15 RECEIVER'S DOCUMENT NUMBER

DD FORM 1348-1 1 AUG 61 DOD SINGLE LINE ITEM RELEASE/RECEIPT DOCUMENT
S/N 0102-013-1700

1

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Figure 12-18.—Single Item Release Receipt Document, DD 1348-1.

utilized or returned to supply. The only exception is when all required parts have not been received for a deadlined vehicle.

LUBRICATION

Proper lubrication is more than merely placing a grease gun on a fitting and pulling the trigger. It means selecting the correct lubricants and applying them in a sufficient amount, in the proper places, to penetrate vehicle parts thoroughly. The experienced mechanic uses neither too much nor too little lubricants.

Lubrication, then, is a thorough job of oiling and greasing. Your shop will likely carry several Navy approved standard lubricants. Learn their specifications and names. This standardization of lubricants eliminates the variation and confusion in manufacturer's brand names and quality designations and makes readily available a few standard lubricants.

Familiarize yourself with the Inspection Guides (Appendixes II and III.) and the lubrication chart of the vehicle with which you are working. The manufacturer of each vehicle provides a lubrication chart (fig. 12-19). These charts show what to lubricate, and where.

Of course, you must learn to use grease guns properly, as well as other dispensers of oils and grease.

Remember that grease on the outside of a fitting does not lubricate, and oil or grease in puddles or gobs around the grease rack can cause serious injury. So look for and remove spilled oil or grease that drops from chassis parts. Better yet, while lubricating a piece of equipment, remove all excessive grease from the fittings and wipe up lubricants that fall to the floor.

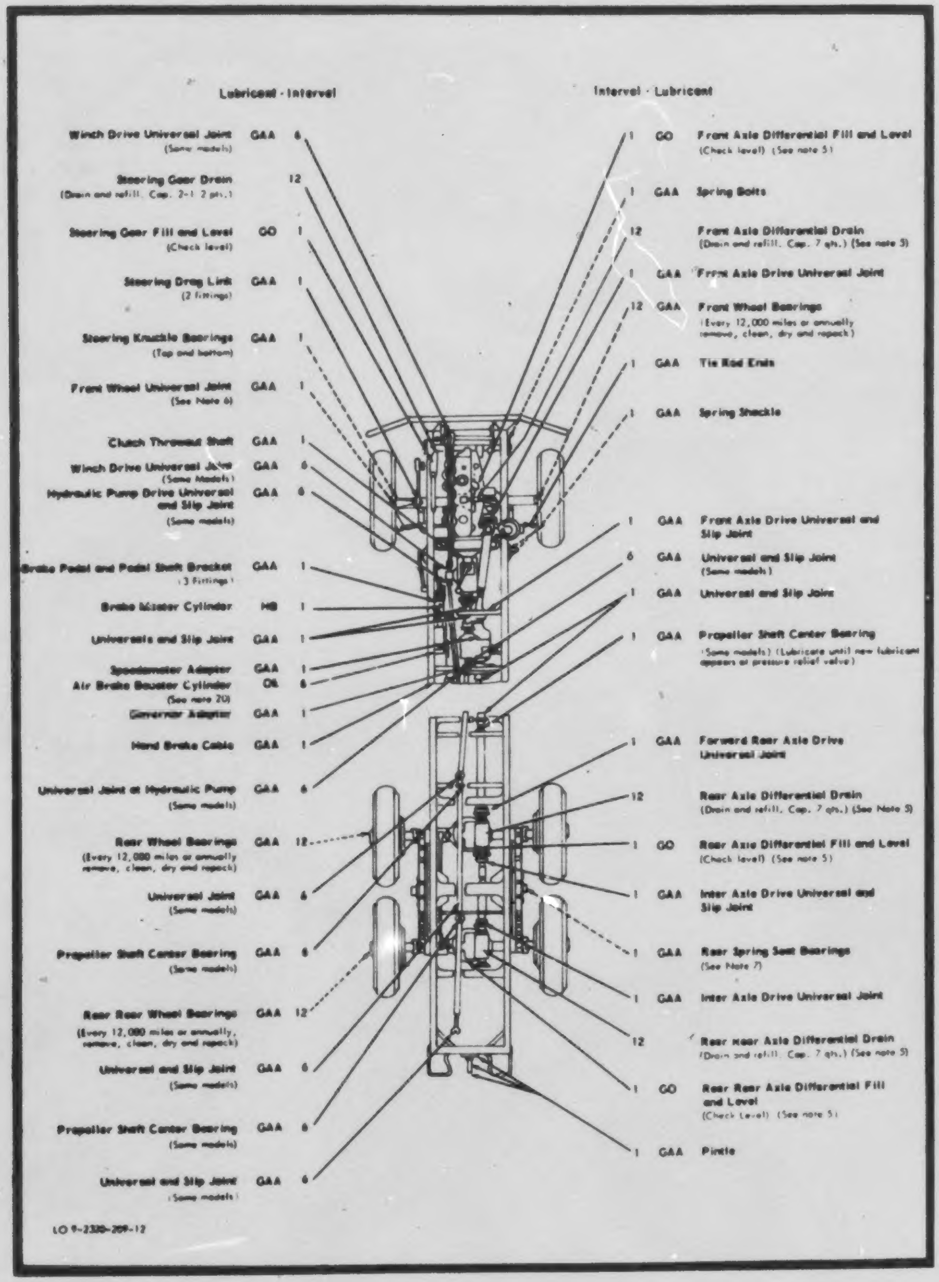
Lubricant · Interval
Winch Drive Universal Joint (Some models) GAA 6
Steering Gear Drain (Drain and refill. Cap. 2-1 2 pts.) 12
Steering Gear Fill and Level (Check level) GO 1
Steering Drag Link (2 fittings) GAA 1
Steering Knuckle Bearings (Top and bottom) GAA 1
Front Wheel Universal Joint (See Note 6) GAA 1
Clutch Throwout Shaft GAA 1
Winch Drive Universal Joint (Some Models) GAA 6
Hydraulic Pump Drive Universal and Slip Joint (Some models) GAA 6
Brake Pedal and Pedal Shaft Bracket (3 Fittings) GAA 1
Brake Master Cylinder HB 1
Universals and Slip Joint GAA 1
Speedometer Adapter GAA 1
Air Brake Booster Cylinder (See note 20) OE 6
Governor Adapter GAA 1
Hand Brake Cable GAA 1
Universal Joint at Hydraulic Pump (Some models) GAA 6
Rear Wheel Bearings (Every 12,000 miles or annually remove, clean, dry and repack) GAA 12
Universal Joint (Some models) GAA 6
Propeller Shaft Center Bearing (Some models) GAA 6
Rear Rear Wheel Bearings (Every 12,000 miles or annually, remove, clean, dry and repack) GAA 12
Universal and Slip Joint (Some models) GAA 6
Propeller Shaft Center Bearing (Some models) GAA 6
Universal and Slip Joint (Some models) GAA 6
LO 9-2320-209-12
Interval · Lubricant
1 GO Front Axle Differential Fill and Level (Check level) (See note 5)
1 GAA Spring Bolts
12 Front Axle Differential Drain (Drain and refill. Cap. 7 qts.) (See note 5)
1 GAA Front Axle Drive Universal Joint
12 GAA Front Wheel Bearings (Every 12,000 miles or annually remove, clean, dry and repack)
1 GAA Tie Rod Ends
1 GAA Spring Shackle
1 GAA Front Axle Drive Universal and Slip Joint
6 GAA Universal and Slip Joint (Some models)
1 GAA Universal and Slip Joint
1 GAA Propeller Shaft Center Bearing (Some models) (Lubricate until new lubricant appears at pressure relief valve)
1 GAA Forward Rear Axle Drive Universal Joint
12 Rear Axle Differential Drain (Drain and refill. Cap. 7 qts.) (See Note 5)
1 GO Rear Axle Differential Fill and Level (Check level) (See note 5)
1 GAA Inter Axle Drive Universal and Slip Joint
1 GAA Rear Spring Seat Bearings (See Note 7)
1 GAA Inter Axle Drive Universal Joint
12 Rear Rear Axle Differential Drain (Drain and refill. Cap. 7 qts.) (See note 5)
1 GO Rear Rear Axle Differential Fill and Level (Check Level) (See note 5)
1 GAA Pintle

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Figure 12-19.—Lubrication chart for a military designed 2 1/2-ton truck.

DISPENSING LUBRICANTS

Grease guns and dispensers operate either by hand or are air operated. You have probably used the hand-operated MUZZLE-LOADER type. The muzzle-loader can be taken apart to load it with grease. This type of grease gun, for the most part, is used only in places hard to reach with a pressure gun, or in lubricating water pumps and other accessories requiring a special lubricant. Lubricants used for most chassis parts, however, are forced through the fittings by guns operated by air pressure.

Crankcase oil is generally dispensed with measured containers or with a hand or air operated pumping system. Hand or air operated systems normally have meters that register the amount of oil dispensed. Gear box lubricants are generally dispensed by some type of hand or air operated pumping system. Be sure you use the right lubricant dispensers. To prevent mistakes, each dispenser is marked to show the grade and type of lubricant it contains.

Before using the lubrication gun, all fittings which are to be lubricated MUST be properly cleaned to avoid forcing dirt into the bearing.

The proper technique for using the lubrication gun is essential. Improper use of the gun can damage the hydraulic coupler jaws and can also damage the fitting. Damaged coupler jaws will prevent the proper seal with fittings. To prevent damage, press the coupler straight onto the CLEAN fitting and squeeze the trigger slowly and smoothly.

When using high pressure guns, take care so that grease seals will not be damaged. To remove the gun, move it up or down or sideways in an arc. Do not pull the gun straight back from the fitting because this will damage the coupler jaws.

CAUTION: Care must be exercised when using a high pressure lube gun on certain lube points. Excessive pressure can damage or "blow off" the grease seals and or dust caps.

After a vehicle is lubricated, clean and fill the grease guns. Then check them to see if they are working properly. Next see that they and other lubricating equipment are stowed in their proper places. Take an inventory of your tools to be sure they are not carried away on the vehicle frame or running board.

Watch for new lubricants and lubrication processes, which are being developed continually. Technical magazines, Navy publications, and your chief are the best sources of information about new developments in lubrication.

CHASSIS LUBRICATION

Most chassis lubrication fittings are located on the front suspension and steering mechanisms. The importance of proper chassis lubrication cannot be overstressed. This lubrication should always be performed in accordance with the manufacturer's lubrication charts.

Some fittings, often referred to as "frozen" fittings, will not readily accept lubricants because it is dry and dirty. Some relative motion in the connection is needed to permit the lubricant to enter the frozen fitting. Rocking the vehicle is the usual method of providing this relative motion in the coupling. In some extreme cases it may be necessary to disassemble the unit being greased in order to properly lubricate it. NEVER pass up a frozen fitting.

BODY LUBRICATION

Cleanliness is the key to body lubrication. Carefully remove any excess lubricant after lubrication since the chassis lubrication points are located where they can easily collect road grit and cause caking. To lubricate the hood, apply a few drops of oil on the fastener-and-release mechanism, coat the fastener pins and hooks with a light application of dry stick lubricant, and close the hood.

Car doors and trunk lids are lubricated by applying a drop or two of oil to the door latch mechanisms. Also apply a few drops of oil to the hinges and swing the door back and forth or raise and lower the lid to spread the lubricant over the contacting surfaces; wipe off any excess lubricant.

The door striker assembly is lubricated by applying a light coating of dry stick lubricant to all sliding surfaces and a few drops of oil to all bearing surfaces. Apply a drop or two of oil around the edge of the cylinder face and to the outer surface of pushbutton latches and press the pushbuttons several times to distribute the lubricant. Wipe off any excess oil and lubricants.

Never use oil to lubricate locks since it collects dust and lint. Inject graphite directly into the keyhole and work the lock several times to distribute the graphite in the tumbler mechanism.

A dry stick lubricant is best used for sliding weather-stripping, surfaces of ashtrays, hinged visors, glove compartments, and other hinged units within the vehicle. Hinged surfaces outside of the vehicle may be lubricated lightly with oil. Always remember that the few minutes required to oil these various items will, in most cases, be well spent because they will probably eliminate failure.

ENGINE AND ENGINE ACCESSORY LUBRICATION

Changing crankcase oil and replacing the oil filter are performed in accordance with the manufacturer's specifications on automotive equipment and at B and C Preventive Maintenance services on construction equipment.

The preferred time to drain the crankcase is immediately after the engine has been run so that the hot oil will drain completely and take along the suspended sludge within the hot oil.

Oil Filter Service

Oil filters remove the physical contaminants of the motor oil, but not the chemical. They are effective also in removing metal chips, carbon, dust, and grit from the oil. The full-flow type of oil filter is integral with the engine. The oil is directed under pressure through the filter and then to the engine bearings. When the oil is too cold to circulate through the filter in the full-flow system, a bypass valve directs the oil around the filter element.

THROW-AWAY OIL FILTER SERVICE.–The throw-away type of oil filter is replaced as a complete unit. You have to disconnect the oil line fittings at the filter. Detach the filter from its bracket and remove the brass fitting from its filter housing. Throw away the filter. Place a bolt or plug into the brass fitting when you are removing or installing it. Brass is malleable (easily bent) and may be crushed by excessive wrench pressure.

SCREW-ON, THROW-AWAY OIL FILTER SERVICE.–The screw-on, throw-away type filter (fig. 12-20) is also replaced as a complete unit. You unscrew the filter from the base by hand and throw the filter away. Wipe the base clean with a cloth, place a small amount of grease or clean lube oil on the new gasket as an added precaution against leakage, and screw a new filter onto the base by hand, tightening at least half a turn after the gasket contacts the base. Start the engine and observe the oil pressure and check for leaks around the oil filter. Stop the engine and add oil to the full level.

REPLACEABLE ELEMENT OIL FILTER SERVICE.–To service the replaceable element oil filter (fig. 12-21), you remove the fastening bolt, lift off the cover or remove the filter shell. Remove the gasket and throw it away. When removing the oil filter of the full-flow type, place a pan under the filter to catch the oil. Take out the old element and throw it away. Throw away the gasket from the top and bottom of the center tube if they are present. Place a pan under the filter and remove the drain plug if the filter is used in the bypass system.

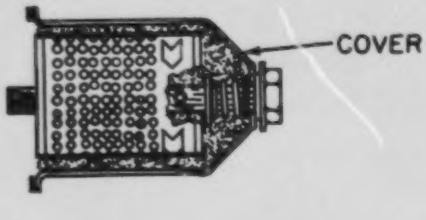

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Figure 12-20.–Replaceable element, full-flow type filter.

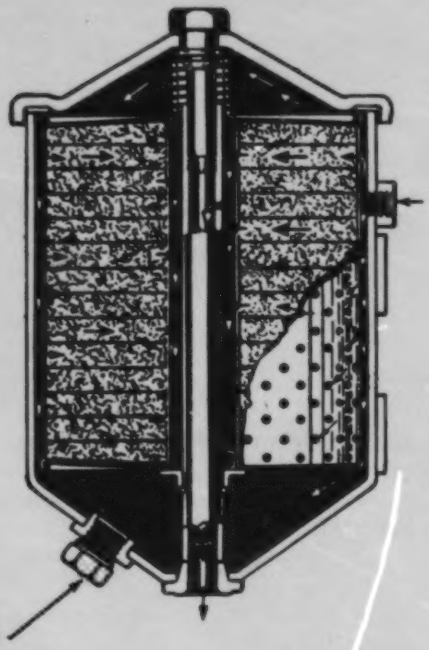

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Figure 12-21.—Replaceable element type filter.

Clean the inside of the filter shell and cover. Install metal supports and a new bottom tube gasket. Insert a new element and a new top tube gasket. Insert a new cover or housing gasket (make sure that the gasket is completely seated in the recess). Replace the cover or housing and fasten the center bolt securely. Fill the crankcase to the full mark on the dip stick with the proper grade and weight of oil. Start and idle the engine. Check the oil pressure immediately and inspect the filter for oil leaks. Then stop the engine and check the crankcase oil level and add oil to the full mark. The final step in the procedure is to mark the mileage on the sticker so that the element of the oil filter will be replaced at the proper interval.

Air Cleaner Service

Air cleaners filter out the dust and grit particles from the air being taken into the fuel system. The three types of air cleaners used by the Navy are the oil bath, wire gauze, and dry type. Air cleaners should be serviced in accordance with the manufacturers' specifications on automotive equipment and at each B and C inspection on construction and allied equipment; more often if operating in dusty areas.

All oil bath cleaners are serviced in a similar manner. You remove and disassemble the unit. On some models the element and reservoir are all you will need to remove. Wash the filter element in solvent until it is thoroughly clean. Shake the excess solvent from the filter element and dry it in the air (don't use compressed air). Empty the reservoir oil and clean the reservoir. Refill the reservoir to the oil level mark. Replace the filter element, cover, and wing nut. Wipe the entire unit with a clean cloth and carefully place the unit on the carburetor air horn.

The wire gauze type air cleaner has no oil reservoir. The mesh filtering element is washed and soaked with oil at each service period. To service the unit, you remove it from the carburetor air horn. Remove the element and wash it in solvent. Shake the excess solvent from the unit and permit it to dry in the air. Oil the wire gauze with motor oil and allow the excess oil to drain. Clean the inside of the filter shell with a clean cloth. Replace the element, cover, and wing nut. Wipe the unit with a clean cloth and replace it on the carburetor air horn.

The dry type carburetor air cleaner uses a paper element. It is serviced by removing the element and shaking and tapping it to remove the dirt.

Manifold Heat Control Valve Service

The manifold heat control valve (fig. 12-22) is another engine accessory which must be lubricated. The manifold heat control valve becomes very hot while operating. A mixture of kerosene, alcohol, or penetrating oil mixed with graphite is used to lubricate the shaft since ordinary lubricant would rapidly burn off. Apply this mixture to both ends while turning the shaft to work the lubricant well into the bearing.

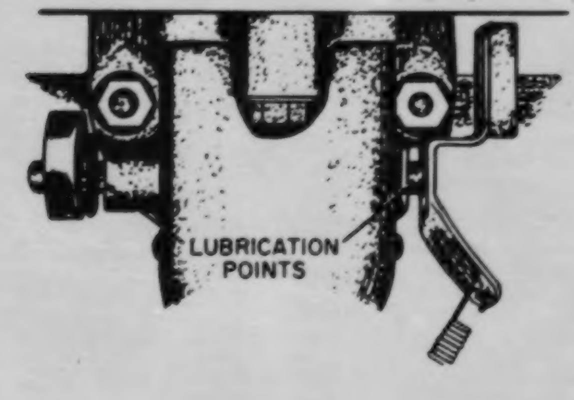

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Figure 12-22.–Typical manifold heat control valve.

Generator Service

Periodic lubrication service is required by most generators. A few generators have sealed bearings which require no lubrication. The generator should be lubricated only at those intervals specified by the manufacturer's lubrication chart.

Distributor Service

The distributor requires service lubrication at two points–the centrifugal spark advance mechanism and the cam.

The centrifugal advance mechanism may be lubricated through a small, round felt wick located at the top of the distributor shaft. Apply two or three drops of motor oil to the felt wick. With your finger tip, apply a light film of high temperature type grease to the cam. CAUTION: Excess lubricant on the cam may be thrown over to the points and cause ignition failure. Electronic ignition distributors need lubrication of the advance mechanism only.

Radiator Fan Service

Most radiator fans are mounted on the water pump shaft and do not require separate lubrication. (Water pump shaft bearings are normally factory lubricated.) However, some radiator fans are equipped with a grease fitting that should be lubricated at regular intervals.

RUNNING GEAR LUBRICATION

The running gear is made up of the mechanisms by which the vehicle is controlled and the units on which the vehicle moves. The steering gear, brake system, and wheel bearings are parts of the running gear system that requires regular lubrication.

Steering Gear Service

The gear housing lubricant level should be checked at every chassis lubrication. You should clean around the fill plug on top of the steering gear housing before removing the fill plug. Do not disturb the adjusting screw locknut adjacent to the fill plug. Check the oil level and add lubricant, if necessary, to bring the oil level to the bottom of the fill plug hole. You then replace the fill plug.

Three points require lubrication in power steering systems. The gear housing is serviced on the linkage type of power steering. As you may recall, the linkage type of power steering system has the power cylinder, and control valve connected to the steering linkage and the steering gear of conventional design. Additional lubrication fittings under the car may be found on the power cylinder or the power cylinder attachment points in the linkage type. The fluid reservoir is serviced at each chassis lubrication by cleaning the area, removing the dip stick or reservoir cover, checking the oil level, and replacing the dip stick or cover after adding oil if necessary. Power systems can become inoperative due to dirt in the system, so use care to prevent dirt from entering the reservoir during service operations.

Brake Service

The hydraulic brake master cylinder fluid level should be checked at every chassis lubrication. The fluid level must be visually checked at the reservoir. Pumping the brake pedal does not constitute a complete check.

Cleanliness is imperative when servicing the master cylinder. You service the master cylinder by cleaning the area around the fill plug or cap, removing the fill plug or cap, checking the fluid level and refilling the master cylinder reservoir to within half an inch below the top of the reservoir. Always use the hydraulic fluid recommended by the manufacturer's lubrication chart. The use of inferior brake fluid or one which contains mineral oil will result in deterioration of the rubber seals, making it necessary to completely overhaul the brake system and flush all brake lines.

Wheel Bearing Service

Wheel bearings should be serviced every time that the brake drums are removed. It is of vital importance that wheel bearing service be performed with utmost care and cleanliness. Most wheel bearing failures result from dirt and grit being introduced to the bearing during lubrication service.

To disassemble the wheel bearings, you should spread out a clean cloth on which to place the parts as you remove them. Remove the outer and inner hubcaps and jack up the wheel until the tire just clears the floor. Remove the cotter pin from the spindle and discard the pin. Then remove the retaining nut and flat washer. Carefully remove the outer bearing and race with an easy shake of the wheel. Do not allow the bearing to drop to the floor. Remove the wheel and inner bearing race from the spindle (ball bearing type—not roll bearing type). You should then clean the loose dust from the brake assembly and the backing plate with a dry brush or compressed air. Next, remove the grease seal from the drum by tapping it out with a brass drift or wood dowel (fig. 12-23). Remove the inner bearing and wash all of the parts except the seal in kerosene or solvent. Be sure that all of the grease is removed. Wipe the old grease from the drum hub and blow the dust from the inside of the drum hub. After this clean the spindle and the inner hub cap by wiping. Then dry all of the parts thoroughly and examine the bearing surfaces for pits, cracks, chips, or general signs of wear. Replace all defective bearings. You should not spin the bearings when they are dry as they can be easily damaged by this action.

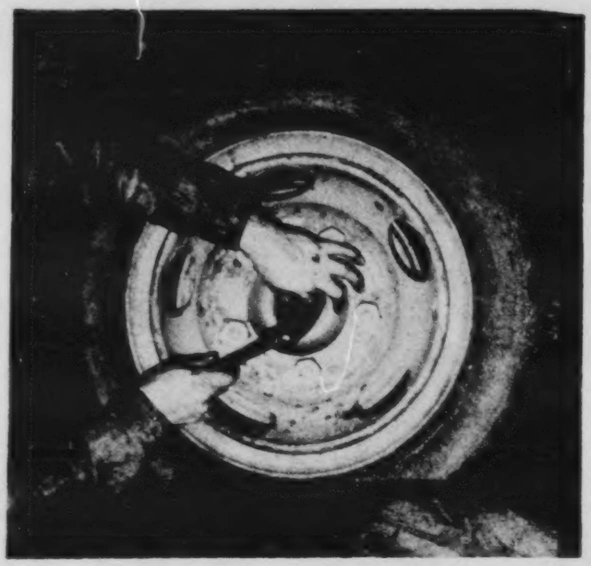

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Figure 12-23.—Tapping out grease seal and inner bearing.

The repacking of the bearings should be done immediately to prevent dust and grit from accumulating on the bearings or in the lubricant. You should use a mechanical bearing packer if it is available. If not, thoroughly pack the lubricant into the bearings with the palm of the hand. You should smear a thin layer of grease inside the wheel hub to prevent rusting; don't pack the inside of the hub with lubricant. The excess lubricant in the hub may possibly get onto the brake linings. Replace the inner bearing and grease seal in the wheel by tapping it into place; use a wood block to protect the seal. (See fig. 12-24.) You should replace any worn or damaged grease seal with a new one.

When replacing the wheel assembly, you should smear a light coat of wheel bearing grease over the spindle and replace the inner bearing. Next, carefully position the wheel on the spindle, taking care to avoid damage to the spindle. Then place the outer bearing and race into the drum hub and tighten the wheel retaining nut according to manufacturer's torque

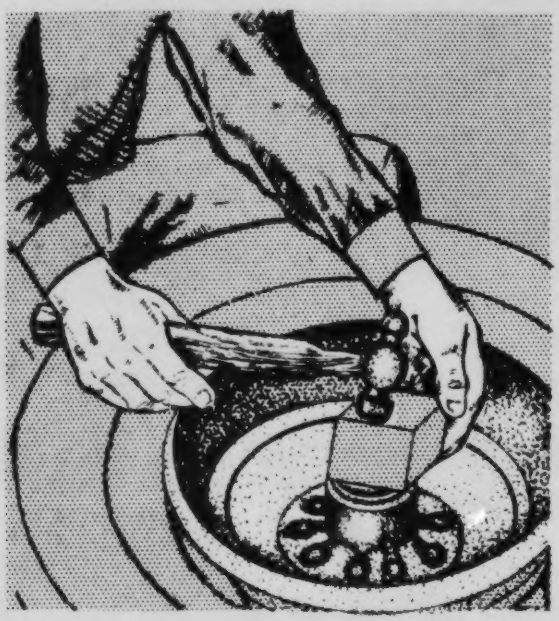

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Figure 12-24.—Replacing inner bearing and grease seal.

specifications. If none is specified, tighten until a noticeable drag is felt when the wheel is rotated, and then loosen the retaining nut to the nearest spindle hole and install a new cotter pin. The wheel should be able to rotate freely at this stage. You may lock the new cotter pin if the wheel is able to rotate freely.

If the wheel does not rotate freely when the retaining nut is loosened and the new cotter pin installed, you should determine the cause of the wheel's dragging. Drag may be caused by dragging brakes, out-of-round brake drums, loose backing plates, or defective bearings or races. You may check bearing looseness by rocking the wheel with one hand at the top and the other hand at the bottom of the tire. The looseness of the king pin or ball joints may be checked in the same way, but observation of the movement will indicate the point of looseness.

After locking the cotter pin, and if the inner hubcap contains a static collector, you should clip the leg of the cotter pin to prevent interference. Then wipe the cap, collector and spindle end to ensure good contact for the radio static collector. You may then replace the inner and outer hubcaps.

POWER TRAIN LUBRICATION

As you may recall, the power train is a series of power transmitting units which carry the vehicle's driving force from the engine to the wheels. The power train consists of the clutch, transmission, drive shaft, universal joint or joints, differential and rear axles.

Clutch Service

The standard clutch is the single-plate, dry disk type. The pedal and clutch shaft bearings are the only lubrication points on this type of clutch. You should refer to the manufacturer's lubrication chart to determine when to lubricate and which lubricant to use. Most of the late model vehicles have a clutch release bearing containing enough lubricant to last for the life of the bearing. Some trucks have a clutch release bearing which requires periodic lubrication. To service the clutch release bearing, you should remove the lower flywheel cover and clean the plug, fitting, or oiler with a clean cloth. Then lubricate sparingly and wipe off any excess lubricant before replacing the lower flywheel cover.

Transmission Service

The conventional transmission should be checked for lubricant level at each chassis lubrication. Recurrent low lubricant level indicates that there is leakage around the oil seals. If you notice foaming in the oil, you should drain the transmission and refill it with fresh lubricant. Foaming is evidence that water or some other lubricant which will not mix with the recommended lubricant is present. You should drain the transmission immediately after the vehicle has been operated. The lubricant will then be warm and will readily drain and take along the suspended contaminants as it drains. Before you drain the oil, you should clean thoroughly around the drain and fill plugs. The drain and fill plugs should be removed to allow the oil to drain. To refill the transmission with oil, you replace the drain plug and fill the transmission with the proper lubricant until it reaches the bottom of the fill plug hole. Then replace the fill plug.

Universal Joint Service

Universal joints are devices designed to transmit power through the drive shaft while flexing through various angles.

Universal joints in use today are either factory lubricated or have lubrication fittings that should be lubricated at regular intervals. Service to those that are factory lubricated is limited to replacement when signs of excessive wear are present. The types provided with lubrication fittings are lubricated with low pressure grease guns only. Use of a high pressure grease gun will damage the seals and result in early failure of the universal joint.

The Hotchkiss drive allows a change in drive shaft length as the vehicle travels over uneven surfaces. A spline in the shaft assembly acts as a slip joint to permit the drive shaft's effective length to vary. Some splines are lubricated from the transmission and some are lubricated through a fitting. The manufacturer's lubrication chart should be used to determine the proper lubricant to use if there is a fitting on the universal joint spline.

Drive Shaft Service

The drive shaft itself is not lubricated, but the drive shaft bearing located in the middle of the drive shaft may require lubrication. Most drive shaft bearings are sealed at the factory and require no lubrication. Those equipped with fittings should be lubricated at regular intervals. You should refer to the manufacturer's lubrication chart to determine the type of lubricant to use and where to apply the lubricant.

Differential Service

The lubrication procedure for the differential varies from model to model; the manufacturer's lubrication chart will indicate the lube points and the amount and type of lubricant to use. Most differentials are filled with lubricant to the bottom of the fill plug. Differentials should be drained after the vehicle has been driven since the warm oil will drain more easily and completely.

MISCELLANEOUS LUBRICATION

There are some vehicle components which do not fall readily into any one category. Electric motors, gearshift levers, and speedometer cables are components which require lubrication service, but which do not fall into any one of the previous categories.

Electric Motor Service

The small electric motors used for automotive accessories are used only intermittently and seldom require lubrication. These electric motors may be equipped with oil impregnated bearings which do not require lubrication. When there is a means to lubricate the motors, you should apply the lubricant sparingly.

Gear Shift Lever Service

You should occasionally lubricate the friction points of the linkage for gearshift levers mounted on steering columns.

Some vehicles with automatic transmissions require that the automatic transmission linkage be lubricated. You should sparingly lubricate the shift detent lever every 1000 miles for those automatic transmissions which have the shift detent lever.

APPENDIX I

THE METRIC SYSTEM

The metric system was developed by French scientists in 1790 and was specifically designed to be an easily used system of weights and measures to benefit science, industry, and commerce. Soon after development, scientists the world over adopted it for their work.

Early in the 19th century many European countries adopted the new system for engineering and commerce. It was possible for these countries to trade manufactured goods with one another and not be concerned with having to buy special wrenches and tools to repair the machinery received in trade. Countries could buy and sell machine tools and precision instruments without having to modify or alter them.

Today, with the exception of the United States and a few small countries, the entire world is using predominantly the metric system, or is committed to its use. It becomes a matter of time until the United States adopts the International System of Units (SI) which is the formal name for the metric system. Exactly when the United States will adopt this system or how long it will take to change from the use of non-SI units to SI units is unknown. Meanwhile, the use of SI units is sure to spread, and is expected to become universal by 1980. Much of the equipment in the United States Navy is already measured in SI units. Certain of its weapons are sized in "metric", such as 20 millimeters and 40 millimeters. Existing maps and charts may show distances in meters (instead of yards) and kilometers (instead of miles).

Some SI units are base units; that is, metric standards defined and adopted by international treaty. Other SI units are derived from the base units and are either expressed in terms of the base unit or are specially named. The base unit for measuring distance is the meter. The metric standard for weight is the gram. Other SI standards include the second (time) and the degree Celsius (temperature), which was formerly called centigrade. The square meter (area), cubic meter (volume), and meter per second (speed) are derived units expressed in terms of the base unit. Derived units having special names include the hertz (frequency), watt (power), farad (capacitance), volt (electromotive force), and ohm (electric resistance).

The metric system is a base-10 (decimal) number system. It is convenient and easy to use because one unit of measure is converted to smaller and larger units of measure by dividing and multiplying by powers of 10, or by shifting the decimal point. For example, 12.3 millimeters convert to 1.23 centimeters. Calculations, such as dividing by 16 (to convert ounces to pounds) and multiplying by 12 (to convert feet to inches) are eliminated.

The result of multiplying a base unit by a power of 10 is referred to as a multiple; the result of dividing by a power of 10, a submultiple. Names of multiples and submultiples of the base unit are formed by adding prefixes to the name of the base unit. The already mentioned millimeter, centimeter, and kilometer are examples. Among the most commonly used prefixes are kilo, mega, centi, and milli. Kilo is the prefix where the base unit is multiplied by 1,000; mega is the prefix where the base unit is multiplied by 1,000,000. Thus, a kilogram is 1,000 times larger than a gram.

Likewise, a megavolt is 1,000,000 times larger than a volt. The prefixes (centi and milli) are submultiples. Centi is the prefix where the base unit is divided by 100; milli, where the base unit is divided by 1,000. Thus, a centimeter is one hundredth of a meter and a milliwatt is one thousandth of a watt.

It is rather simple to relate SI units to non-SI units. Compared to the yard, the meter is a little longer (about 1.1 yd). In long distance measurements, the SI unit is the kilometer, which is slightly farther than 1/2 mile (about 0.6 mile). The basic unit of volume, the liter, is a little larger than a quart (about 1.06 qt). The weight of a liter of pure water is 1 kilogram, which is a little more than 2 pounds (about 2.2 lb). The SI unit for measuring power, the kilowatt, is somewhat bigger than one horsepower (about 1.3 hp).

In working with non-SI units and SI units, it helps to have a table of common equivalent weights and measures, such as the one that follows. This table also gives the factor you multiply by in order to convert a non-SI unit to an SI unit, or vice versa. For example:

1/2 inch = 1/2 x 25.4 or 12.7 mm (exact)

5 kilometers = 5 x 0.6 or 3 miles (approximate)

SI AND NON-SI UNITS OF MEASUREMENT

COMMON EQUIVALENTS AND CONVERSIONS

Approximate Common Equivalents		Conversions Accurate to Parts Per Million (units stated in abbreviated form)	
		Number X Factor	
1 inch	= 25 millimeters	in X 25.4*	= mm
1 foot	= 0.3 meter	ft X 0.3048*	= m
1 yard	= 0.9 meter	yd X 0.9144*	= m
1 mile[†]	= 1.6 kilometers	mi X 1.60934	= km
1 square inch	= 6.5 square centimeters	in^2 X 6.4516*	= cm^2
1 square foot	= 0.09 square meter	ft^2 X 0.0929030	= m^2
1 square yard	= 0.8 square meter	yd^2 X 0.836127	= m^2
1 acre	= 0.4 hectare	acres X 0.404686	= ha
1 cubic inch	= 16 cubic centimeters	in^3 X 16.3871	= cm^3
1 cubic foot	= 0.03 cubic meter	ft^3 X 0.0283168	= m^3
1 cubic yard	= 0.8 cubic meter	yd^3 X 0.764555	= m^3
1 quart (lq.)	= 1 liter	qt (lq.) X 0.946353	= *l*
1 gallon	= 0.004 cubic meter	gal X 0.00378541	= m^3
1 ounce (avdp)	= 28 grams	oz (avdp) X 28.3495	= g
1 pound (avdp)	= 0.45 kilogram	lb (avdp) X 0.453592	= kg
1 horsepower	= 0.75 kilowatt	hp X 0.745700	= kW
1 pound per square inch	= 0.07 kilogram per square centimeter	psi X 0.0703224	= kg/cm^2
1 millimeter	= 0.04 inch	mm X 0.0393701	= in
1 meter	= 3.3 feet	m X 3.28084	= ft
1 meter	= 1.1 yards	m X 1.09361	= yd
1 kilometer	= 0.6 mile	km X 0.621371	= mi
1 square centimeter	= 0.16 square inch	cm^2 X 0.155000	= in^2
1 square meter	= 11 square feet	m^2 X 10.7639	= ft^2
1 square meter	= 1.2 square yards	m^2 X 1.19599	= yd^2
1 hectare	= 2.5 acres	ha X 2.47105	= acres
1 cubic centimeter	= 0.06 cubic inch	cm^3 X 0.0610237	= in^3
1 cubic meter	= 35 cubic feet	m^3 X 35.3147	= ft^3
1 cubic meter	= 1.3 cubic yards	m^3 X 1.30795	= yd^3
1 liter	= 1 quart (lq.)	*l* X 1.05669	= qt (lq.)
1 cubic meter	= 250 gallons	m^3 X 264.172	= gal
1 gram	= 0.035 ounces (avdp)	g X 0.0352740	= oz (avdp)
1 kilogram	= 2.2 pounds (avdp)	kg X 2.20462	= lb (avdp)
1 kilowatt	= 1.3 horsepower	kW X 1.34102	= hp
1 kilogram per square centimeter	= 14.2 pounds per square inch	kg/cm^2 X 14.223226	= psi

[†] nautical mile = 1.852 kilometers

* exact

APPENDIX II

NCF AUTOMOTIVE EQUIPMENT INSPECTION GUIDE

ITEM	SERVICE			ITEM DESCRIPTION
	A	B	C	
1		X	X	VALVE MECHANISM–Adjust valves as the need for service is indicated by valve noises or engine performance.
2		X	X	IGNITION SYSTEM–Check magneto points and impulse coupling; adjust as required. Check condition of distributor cap, rotor, breaker points. Set timing. Check distributor spark advance.
3		X	X	SPARK PLUGS–Clean, check, and gap spark plugs. Replace as required.
4	X	X	X	FUEL SYSTEM–Check fuel filter and fuel pump screens and bowls; clean or replace as required. Adjust idle speed and fuel mixture as required.
5	X	X	X	CHOKE AND THROTTLE CONTROLS–Check the choke, throttle linkage, engine shutoff and emergency shutoff for proper operation.
6		X	X	GOVERNOR–Inspect all linkage and pins for wear and the operating efficiency of the governor under varying load conditions. Notice signs of surging or improper operation. Lubricate as required. Using speed indicator, check engine governed speed.
7	X	X	X	FUEL TANK & SHUTOFF VALVES–Inspect fuel tanks for condition and security of mounting brackets. Check for plugged air vents. Check shutoff valve for operation and leaks. Check fuel lines for leaks or chafing.
8	X	X	X	LIGHTS–Inspect all lights, signals and reflectors. Check condition of trailer jumper cables and junction boxes on truck tractors. Visually check headlight alinement.

ITEM	SERVICE			ITEM DESCRIPTION
	A	B	C	
9	X	X	X	BATTERY–Check water level. Clean battery and terminal connections. Check holddown bolts and brackets.
10		X	X	STARTER–Check to see that the mounting bolts are tight and that the cable connections are clean and tight.
11	X	X	X	INSTRUMENTS AND CONTROLS–Check all instruments, gages, switches, controls, and warning devices for proper operation.
12	X	X	X	COOLING SYSTEMS–Fill radiator, check and tighten hose connections. Clean and straighten radiator fins as necessary. Test antifreeze in season. Check radiator mounts. On "C" PM's, drain and refill radiator, flush cooling system if required.
13	X	X	X	FAN ASSEMBLY AND FAN BELTS–Inspect fan assembly. Inspect fan belts for wear and frayed edges, adjust tension in accordance with manufacturer's specifications.
14	X	X	X	EXHAUST SYSTEM–Check for exhaust and muffler leakage. Check rain caps.
15	X	X	X	CLUTCH–Check for clutch slippage. Check to see that free travel is in accordance with manufacturer's specifications.
16	X	X		HYDRAULIC BRAKES–Check pedal clearances and brake hose condition. Road test to determine if brakes function properly.
17	X	X		FULL AIR OR AIR OVER HYDRAULIC BRAKES–Drain air reservoirs. Check air pressure buildup. Check brake chamber pushrod. Check quick application valve and for complete release of all brakes. Check tractor protection valve controls in normal and emergency positions. Check operation of emergency brake application for trailers. Check brake hose condition. Road test to determine if brakes function properly.
18			X	ALL BRAKES–Remove front drums and one rear drum and inspect for wear and damage. Check and lube wheel bearings as required. Then do item 16 or 17 as applicable.

ITEM	SERVICE			ITEM DESCRIPTION
	A	B	C	
19	X	X	X	LEAKS–Visually inspect the engine compartment, brake drums, and beneath the vehicle for indications of water, fluid, oil, or fuel leaks.
20	X	X	X	LUBRICATE–Lubricate utilizing lube charts and manufacturer's specifications. On "C" PM's, drain and refill all gear box reservoirs; flush if required.
21		X	X	ENGINE OIL AND OIL FILTER–Change oil and replace filters.
22	X	X	X	AIR CLEANER–Check screens and oil level and service as necessary. Replace paper-type elements as required.
23		X	X	TRUNNION AXLE BEARING–Lubricate.
24	X	X	X	PCV VALVE–Check positive crankcase ventilation system for proper operation. Clean or replace components as required.
25	X	X	X	VACUUM BRAKE BOOSTER AIR CLEANER–Clean and lubricate.
26	X	X	X	TURBOCHARGERS, SUPERCHARGER–Check for leaks and proper operation.
27	X	X	X	GEAR BOXES–Check mounting and assembly bolts, breathers, lube levels, indications of leaking gaskets or seals.
28			X	AUTOMATIC TRANSMISSION–Do item 27, then check automatic transmission in accordance with the vehicle manufacturer's recommended procedures. Check and adjust shifting linkage.
29	X	X	X	UNIVERSAL AND SLIP JOINTS–Inspect and lubricate U-joints and slip joints in accordance with manufacturer's recommendations. Tighten all drive line bolts.
30	X	X	X	HYDRAULIC SYSTEM–Check lines for leaks, packing glands for adjustment, and controls for excessive wear. Check reservoir fluid level and vent openings. Clean or replace screens/filters as required. On "C" PM's, drain and refill hydraulic system; flush if required.

ITEM	SERVICE			ITEM DESCRIPTION
	A	B	C	
31	X	X	X	AIR COMPRESSOR, VALVES AND LINES–Check oil level; add as necessary. Clean air filters; drain water traps. Check compressor, unloader safety valve, belts, pulleys, and adjust in accordance with manufacturer's specifications. Check for leaks.
32	X	X	X	STEERING SYSTEM–With the weight of the vehicle on its wheels, check the steering linkage for excessive looseness and alinement; if necessary, adjust the steering system in accordance with manufacturer's recommended procedures.
33	X	X	X	DIFFERENTIAL–Check lube levels. Check for unusual noises and indications of leaking gaskets or seals.
34	X	X	X	AXLES–Retighten axle flange nuts. Check for leaks.
35	X	X	X	TIRES–Check for cuts, bruises, uneven wear, inflation, and proper sizes. Replace missing valve caps. Check for matching tire size of duals, tandem bogies, and multidrives (4x4's, 6x6's, and so on).
36	X	X	X	WHEELS–Check for rim damage and inspect for worn and elongated stud holes. Retighten all lug nuts.
37	X	X	X	SPRINGS–Check for broken leaves or coils, loose U-bolts or shackles.
38	X	X	X	SHOCK ABSORBERS–Check for leakage. If faulty shock absorber action is suspected, remove the shock absorbers and perform bench tests in accordance with manufacturer's recommended procedures.
39	X	X	X	FRAME–Check crossmembers, side rails, brackets, welds, bolts, and rivets for condition and alinement.
40	X	X	X	FIFTH WHEEL–Check fifth wheel mounting plate, mounting plate bolts and safety lock. Check for cracked frame rails.
41	X	X	X	ENGINE AND TRANSMISSION MOUNTINGS–Inspect supports for looseness or breaks.

ITEM	SERVICE			ITEM DESCRIPTION
	A	B	C	
42	X	X	X	CAB–Check doors, windows, glass, seats, cushions, mirrors, body bolts, frames, sheet metal, paint and identification markings, and floors, and see that drain holes are unobstructed.
43	X	X	X	ACCIDENT DAMAGE–Inspect for accident damage, loose or defective parts.
44	X	X	X	WINDSHIELD WIPERS–Check the windshield wipers for condition and proper operation.
45	X	X	X	SAFETY GUARDS–Check all safety guards and be sure they are properly installed, secure, and in good condition.
46	X	X	X	TRAILER AND SEMITRAILER–Perform applicable operations. Check kingpins for wear. Lubricate landing gear.
47	X	X	X	PARTS & COMPONENTS–Check miscellaneous parts and components (collateral equippage) as required.

APPENDIX III

NCF CONSTRUCTION EQUIPMENT INSPECTION GUIDE

ITEM	SERVICE			ITEM DESCRIPTION
	A	B	C	
1		X	X	VALVE MECHANISM–Adjust valves as the need for service is indicated by valve noises or engine performance.
2		X	X	IGNITION SYSTEM–Check magneto points and impulse coupling; adjust as required. Check condition of distributor cap, rotor, and breaker points. Set timing. Check distributor spark advance.
3		X	X	SPARK PLUGS–Clean, check, and gap spark plugs. Replace as required.
4	X	X	X	FUEL SYSTEM–Check fuel filter and fuel pump screens and bowls; clean or replace as required.
5	X	X	X	CHOKE AND THROTTLE CONTROLS–Check the choke, throttle linkage, engine shutoff and emergency shutoff for proper operation.
6		X	X	GOVERNOR–Inspect all linkage and pins for wear and the operating efficiency of the governor under varying load conditions. Notice signs of surging or improper operation. Lubricate as required. Using speed indicator, check engine governed speed.
7	X	X	X	FUEL TANK & SHUTOFF VALVES–Inspect fuel tanks for condition and security of mounting brackets. Check for plugged air vents. Check shutoff valve for operation and leaks. Check fuel lines for leaks or chafing.
8	X	X	X	LIGHTS–Inspect all lights, signals and reflectors.

ITEM	SERVICE			ITEM DESCRIPTION
	A	B	C	
9	X	X	X	BATTERY–Check water level. Clean battery and terminal connections. Check holddown bolts and brackets.
10		X	X	GENERATORS–Check bearing seals for leaks. Clean dust and oil from air passages. Check condition of slip ring, commutator, and brushes for wear and proper alinement. Instruments must function properly. Lubricate as required.
11		X	X	STARTER–Check to see that the mounting bolts are tight and that the cable connections are clean and tight.
12	X	X	X	INSTRUMENTS AND CONTROLS–Check all instruments, gages, switches, controls and warning devices for proper operation.
13		X	X	WATER CHARGE AND TIME DEVICE–Inspect for functional accuracy and operation.
14	X	X	X	COOLING SYSTEMS–Fill radiator; check and tighten hose connections. Clean and straighten radiator fins as necessary. Test antifreeze in season. Check radiator mounts. On "C" PM's, drain and refill radiator; flush cooling system if required.
15	X	X	X	FAN ASSEMBLY AND FAN BELTS–Inspect fan assembly. Inspect fan belts for wear and frayed edges; adjust tension in accordance with manufacturer's specifications.
16	X	X	X	EXHAUST SYSTEM–Check for exhaust and muffler leakage. Check rain caps.
17	X	X	X	CLUTCH–Check for clutch slippage. Check to see that free travel is in accordance with manufacturer's specifications. Check jaw type for wear.
18	X	X		HYDRAULIC BRAKES–Check pedal clearances for free travel and brake hose condition. Operate to determine if brakes function properly.
19	X	X		FULL AIR OR AIR OVER HYDRAULIC BRAKES–Drain air reservoirs. Check air pressure buildup. Check brake chamber pushrod. Check operation of quick application valve and for complete release of all brakes. Check tractor protection valve

ITEM	SERVICE			ITEM DESCRIPTION
	A	B	C	
				controls in normal and emergency positions. Check operation of emergency brake application for trailers. Check brake hose condition. Road test to determine if brakes function properly.
20			X	ALL BRAKES–Remove front drums and one rear drum and inspect for wear and damage. Check and lube wheel bearings as required. Then do item 18 or 19 as applicable.
21	X	X	X	LEAKS–Visually inspect the engine compartment, brake drums, and beneath the vehicle for indications of water, fluid, oil, or fuel leaks.
22	X	X	X	LUBRICATE–Lubricate, utilizing lube charts and manufacturer's specifications. On "C" PM's, drain and refill all gear box reservoirs; flush if required.
23		X	X	ENGINE OIL AND OIL FILTER–Change oil and replace filters. Inspect all external engine oil lines for condition and leakage.
24	X	X	X	AIR CLEANER–Check screens and oil level and service as necessary. Replace paper-type elements as required.
25	X	X	X	TURBOCHARGERS, SUPERCHARGERS–Check for leaks and proper operation.
26	X	X	X	GEAR BOXES–Check mounting and assembly bolts, breathers, lube levels, and indications of leaking gaskets or seals.
27			X	AUTOMATIC TRANSMISSION–Do item 26, then check automatic transmission in accordance with the vehicle manufacturer's recommended procedures. Check and adjust shifting linkage.
28	X	X	X	EXPOSED DRIVE CHAINS–Check for wear and broken and cracked links, rollers and tension.
29	X	X	X	BELTS, DRIVE–Inspect for alinement wear and frayed edges. Adjust in accordance with manufacturer's specifications.
30	X	X	X	UNIVERSAL AND SLIP JOINTS–Inspect and lubricate U-joints and slip joints in accordance with

ITEM	SERVICE			ITEM DESCRIPTION
	A	B	C	
				manufacturer's recommendations. Tighten all drive line bolts.
31	X	X	X	AIR COMPRESSOR, VALVES AND LINES–Check oil level; add oil as necessary. Clean air filters, and drain water traps. Check compressor, unloader, safety valve, belts and pulleys, and adjust in accordance with manufacturer's specifications. Check for leaks.
32	X	X	X	HYDRAULIC SYSTEM–Check lines for leaks, packing glands for adjustment, and controls for excessive wear. Check reservoir fluid level and vent openings. Clean or replace screens/filters as required. On "C" PM's, drain and refill hydraulic system; flush if required.
33	X	X	X	STEERING SYSTEM–With the weight of the vehicle on its wheels, check the steering linkage for excessive looseness and alinement; if necessary, adjust the steering system in accordance with manufacturer's recommended procedures.
34	X	X	X	DIFFERENTIAL–Check lube levels. Check for unusual noises and indications of leaking gaskets or seals.
35	X	X	X	FINAL DRIVES–Check lube levels, security of bolts and capscrews, and indications of leaking gaskets and seals.
36	X	X	X	TIRES–Check for cuts, bruises, uneven wear, inflation, and proper sizes. Replace missing valve caps. Check for matching tire size of duals, tandem bogies, and multidrives (4x4's, 6x6's, and so on).
37	X	X	X	WHEELS–Check for rim damage and inspect for worn and elongated stud holes; retighten all lug nuts.
38		X	X	CRAWLER TRACK ASSEMBLY–Check plates, linkage, pins, and bushings for wear. Check track shoe mounting. Inspect and adjust track tension in accordance with manufacturer's instructions.
39	X	X	X	SPROCKETS–Check for tooth wear and alinement.
40	X	X	X	ROLLERS–Check for oil leaks, broken flanges, flat spots, and worn faces. Rollers should turn freely.

ITEM	SERVICE			ITEM DESCRIPTION
	A	B	C	
41	X	X	X	SPRINGS–Check for broken leaves or coils, and loose U-bolts or shackles.
42	X	X	X	FRAME–Check crossmembers, side rails, brackets, welds, bolts and rivets for condition and alinement.
43	X	X	X	ENGINE MOUNTS–Loose holddown bolts will result in the loss of the original shims from the support pads and misalinement. If engine shows evidence of being adrift, it should be realined and properly secured.
44	X	X	X	CAB–Check doors, windows, glass, seats, cushions, mirrors, body bolts, frames, sheet metal, paint and identification markings, and floors, and see that drain holes are unobstructed.
45	X	X	X	ACCIDENT DAMAGE–Inspect for accident damage, loose or defective parts.
46	X	X	X	WINDSHIELD WIPERS–Check the windshield wipers for condition and proper operation.
47	X	X	X	SAFETY GUARDS–Check all safety guards and be sure they are properly installed, secure, and in good condition.
48	X	X	X	POWER CONTROL UNITS–Cable-type; check oil levels and leaks and worn or glazed linings and bands. Hydraulic type; check operation of control valves and pumps. Inspect piston rods and linkage for wear. Check for leaks.
49	X	X	X	BUCKETS–Check for loose plates, rivets, welds, fasteners, tooth and bit holders, and improper working latches.
50	X	X	X	CUTTING EDGES AND END BITS–Check attaching bolts or clips. Check the distance that wear is approaching moldboard or bit holder.
51	X	X	X	BEARINGS AND BUSHINGS–Inspect grease seals for leaks. Check bearings for adjustment and alinement. Lubricate as required.
52	X	X	X	MOLDBOARD AND LIFT ARMS–Check pins, pivot socket, bolts, welds, and shifting mechanism. Check lift

ITEM	SERVICE			ITEM DESCRIPTION
	A	B	C	
				and sidearms for bends and worn linkage. See that pin keepers are in place.
53	X	X	X	FAIRLEADS–Check sheaves, rollers, and mounting.
54	X	X	X	TAGLINE–Check in accordance with manufacturer's instructions.
55	X	X	X	CABLES AND SHEAVES–Inspect condition of cables and attachments, replace in accordance with manufacturer's instructions. Check sheaves, pins, and bearings for wear and broken flanges.
56	X	X	X	BOOM AND LEADS–Check crossmembers, side rails, brackets, welds, bolts, and rivets for condition and alinement. Check boom harness for defective cables, pins and sheaves.
57	X	X	X	DIPPER STICK AND RACKING–Check for general condition and alinement. Note any cracks, breaks, loose bolts or rivets.
58	X	X	X	CROWD ASSEMBLY–Check for proper operation. Adjustment should be made according to the manufacturer's instructions.
59	X	X	X	BOOM AND HOIST DRUM ASSEMBLIES–Check drum bearings, bushings, shafting, grease seals, and lagging.
60	X	X	X	SWING MECHANISM–Inspect gears, circle, roller path, fins, roller shafts, and bearing seals for wear. Rollers should rotate freely. Swing locks and linkage must operate properly.
61		X	X	CENTER PIN, HOUSE CARRIER AND HOLDDOWN ROLLERS–Inspect for wear. Adjust to manufacturer's specifications.
62		X	X	TRAVEL MECHANISM–Inspect and adjust clutches. Inspect travel lock, shafts and linkage for excessive wear.
63	X	X	X	GEARS AND PINIONS–Check open gears and pinions for proper lubrication.

ITEM	SERVICE A	SERVICE B	SERVICE C	ITEM DESCRIPTION
64	X	X	X	HAMMER LINKS–Check for bending and elongated mounting bolt holes.
65	X	X	X	JAWS, LINERS AND CONCAVES–Check for wear and secure mounting.
66		X	X	TOGGLE ASSEMBLY–Check plates, seats, wedges, and ways for wear, cracks, and breaks. Check tension spring for adjustment.
67	X	X	X	ECCENTRIC SHAFT OR SLEEVE–Check for wear and lube leaks.
68	X	X	X	CONVEYORS AND DRIVES–Check condition of belts and splices, alinement, scrapers and cleaners, tail pulley, chains and buckets, sprockets and safety guards.
69	X	X	X	SCREEN AND DRIVES–Check for wear, mounting, alinement, and operation. See that rivets, bolts, and braces are in place and secure.
70	X	X	X	BINS, HOPPERS AND CHUTES–Check braces and fastenings. Inspect operation of gates and controls.
71	X	X	X	MIXER DRUM–Check cleanliness of drum and mixing flight, chutes, bearings, and trunnion rollers for wear.
72	X	X	X	PARTS AND COMPONENTS–Check miscellaneous parts and components as required.

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CONSTRUCTION MECHANIC 3 & 2

NAVEDTRA 10644-G

Prepared by the Naval Education and Training Program Development
Center, Pensacola, Florida

Your NRCC contains a set of assignments and self-scoring answer sheets (packaged separately). The Rate Training Manual, CONSTRUCTION MECHANIC 3&2, NAVEDTRA 10644-G , is your textbook for the NRCC. If an errata sheet comes with the NRCC, make all indicated changes or corrections. Do not change or correct the textbook or assignments in any other way.

HOW TO COMPLETE THIS COURSE SUCCESSFULLY

Study the textbook pages given at the beginning of each assignment before trying to answer the items. Pay attention to tables and illustrations as they contain a lot of information. Making your own drawings can help you understand the subject matter. Also, read the learning objectives that precede the sets of items. The learning objectives and items are based on the subject matter or study material in the textbook. The objectives tell you what you should be able to do by studying assigned textual material and answering the items.

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Your NRCC will be administered by your command or, in the case of small commands, by the Naval Education and Training Program Development Center. No matter who administers your course you can complete it successfully by earning grades that average 3.2 or higher. If you are on active duty, the average of your grades in all assignments must be at least 3.2. If you are NOT on active duty, the average of your grades in all assignments of each creditable unit must be at least 3.2. The unit breakdown of the course, if any, is shown later under Naval Reserve Retirement Credit.

WHEN YOUR COURSE IS ADMINISTERED BY LOCAL COMMAND

As soon as you have finished an assignment, submit the completed self-scoring answer sheet to the officer designated to administer it. He will check the accuracy of your score and discuss with you the items that you do not understand. You may wish to record your score on the assignment itself since the self-scoring answer sheet is not returned.

If you are completing this NRCC to become eligible to take the fleetwide advancement examination, follow a schedule that will enable you to complete all assignments in time. Your schedule should call for the completion of at least one assignment per month.

Although you complete the course successfully, the Naval Education and Training Program Development Center will not issue you a letter of satisfactory completion. Your command will make a note in your service record, giving you credit for your work.

WHEN YOUR COURSE IS ADMINISTERED BY THE NAVAL EDUCATION AND TRAINING PROGRAM DEVELOPMENT CENTER

After finishing an assignment, go on to the next. Retain each completed self-scoring answer sheet until you finish all the assignments in a unit (or in the course if it is not divided into units). Using the envelopes provided, mail your self-scored answer sheets to the Naval Education and Training Program Development Center where the scores will be verified and recorded. Make sure all blanks at the top of each answer sheet are filled in. Unless you furnish all the information required, it will be impossible to give you credit for your work. You may wish to record your scores on the assignments since the self-scoring answer sheets are not returned.

The Naval Education and Training Program Development Center will issue a letter of satisfactory completion to certify successful completion of the course (or a creditable unit of the course). To receive a course-completion letter, follow the directions given on the course-completion form in the back of this NRCC.

You may keep the textbook and assignments for this course. Return them only in the event you disenroll from the course or otherwise fail to complete the course. Directions for returning the textbook and assignments are given on the book-return form in the back of this NRCC.

PREPARING FOR YOUR ADVANCEMENT EXAMINATION

Your examination for advancement is based on the Manual of Naval Enlisted Manpower Personnel Classifications and Occupational Standards (NAVPERS 18068D). The sources of questions in this examination are given in the Bibliography for Advancement Study (NAVEDTRA 10052). Since your NRCC and textbook are among the sources listed in this bibliography, be sure to study both in preparing to take your advancement examination. The qualifications for your rating may have changed since your course and textbook were printed, so refer to the latest editions of NAVPERS 18068 and NAVEDTRA 10052.

NAVAL RESERVE RETIREMENT CREDIT

This course is evaluated at 18 Naval Reserve retirement points. These points are creditable to personnel eligible to receive them under current directives governing retirement of Naval Reserve personnel. Points will be credited in units upon satisfactory completion of the assignments as follows:

Units	Points	Assignments
1	12	1 through 8
2	6	9 through 12

Credit cannot be given again for this course if the student has previously received credit for completing another Construction Mechanic NRCC or ECC.

COURSE OBJECTIVE

In completing this NRCC, you will demonstrate a knowledge of the subject matter by correctly answering items on the following: career development; operating principles, component functions, and maintenance procedures of fuel systems, cooling systems and lubricating systems of internal combustion engines; electrical systems, power trains, suspension systems, and brake systems common to automotive, materials-handling, and construction equipment; and principles and techniques of preventive maintenance.

While working on this nonresident career course, you may refer freely to the text. You may seek advice and instruction from others on problems arising in the course, but the solutions submitted must be the result of your own work and decisions. You are prohibited from referring to or copying the solutions of others, or giving completed solutions to anyone else taking the same course.

Naval nonresident career courses may include a variety of items -- multiple-choice, true-false, matching, etc. The items are not grouped by type; regardless of type, they are presented in the same general sequence as the textbook material upon which they are based. This presentation is designed to preserve continuity of thought, permitting step-by-step development of ideas. Some courses use many types of items, others only a few. The student can readily identify the type of each item (and the action required of him) through inspection of the samples given below.

MULTIPLE-CHOICE ITEMS

Each item contains several alternatives, one of which provides the best answer to the item. Select the best alternative and erase the appropriate box on the answer sheet.

SAMPLE

s-1. The first person to be appointed Secretary of Defense under the National Security Act of 1947 was
1. George Marshall
2. James Forrestal
3. Chester Nimitz
4. William Halsey

The erasure of a correct answer is indicated in this way on the answer sheet:

	1 T	2 F	3	4	
s-1	■	C	■	■	

TRUE-FALSE ITEMS

Determine if the statement is true or false. If any part of the statement is false the statement is to be considered false. Erase the appropriate box on the answer sheet as indicated below.

SAMPLE

s-2. Any naval officer is authorized to correspond officially with a bureau of the Navy Department without his commanding officer's endorsement.

The erasure of a correct answer is also indicated in this way on the answer sheet:

	1 T	2 F	3	4	
s-2	■	CC	■	■	

MATCHING ITEMS

Each set of items consists of two columns, each listing words, phrases or sentences. The task is to select the item in column B which is the best match for the item in column A that is being considered. Items in column B may be used once, more than once, or not at all. Specific instructions are given with each set of items. Select the numbers identifying the answers and erase the appropriate boxes on the answer sheet.

SAMPLE

In items s-3 through s-6, match the name of the shipboard officer in column A by selecting from column B the name of the department in which the officer functions.

A. Officers	B. Departments
s-3. Damage Control Assistant	1. Operations Department
s-4. CIC Officer	2. Engineering Department
s-5. Assistant for Disbursing	3. Supply Department
s-6. Communications Officer	

The erasure of a correct answer is indicated in this way on the answer sheet:

	1 T	2 F	3	4	
s-3	■	C	■	■	
s-4	C	■	■	■	
s-5	■	■	C	■	
s-6	C	■	■	■	

How To Score Your Immediate Knowledge of Results (IKOR) Answer Sheets

	1 T	2 F	3	4	
1	■	C	6	■	1
2	C	9	■	9	2
3	■	■	C	■	
4	CC	12	■	■	1

Total the number of incorrect erasures (those that show page numbers) for each item and place in the blank space at the end of each item.

Sample only

Number of boxes erased incorrectly	0-2	3-7	8-
Your score	4.0	[✓ 3.9]	3.8

Now TOTAL the column(s) of incorrect erasures and find your score in the Table at the bottom of EACH answer sheet.

NOTICE: If, on erasing, a page number appears, review text (starting on that page) and erase again until "C", "CC", or "CCC" appears. For courses administered by the Center, the maximum number of points (or incorrect erasures) will be deducted from each item which does NOT have a "C", "CC", or "CCC" uncovered (i.e., 3 pts. for four choice items, 2 pts. for three choice items, and 1 pt. for T/F items).

Assignment 1

Preparation for Advancement; Principles of Internal Combustion Engines

Textbook, NAVEDTRA 10644-G: Pages 1 - 27

In this course you will demonstrate that learning has taken place by correctly answering training items. The mere physical act of indicating a choice on an answer sheet is not in itself important; it is the *mental* achievement, in whatever form it may take, prior to the physical act that is important and toward which course *learning objectives* are directed. The selection of the correct choice for a course training item indicates that you have fulfilled, at least in part, the stated objective(s).

The accomplishment of certain objectives, for example, a *physical* act such as drafting a memo, cannot readily be determined by means of objective type course items; however, you can demonstrate by means of answers to training items that you have acquired the requisite knowledge to perform the physical act. The accomplishment of certain other learning objectives, for example, the *mental* acts of comparing, recognizing, evaluating, choosing, selecting, etc., may be readily demonstrated in a course by indicating the correct answers to training items.

The *comprehensive* objective for this course has already been given. It states the purpose of the course in terms of what you will be able to do as you complete the course.

The *detailed* objectives in each assignment state what you should accomplish as you progress through the course. They may appear singly or in clusters of closely related objectives, as appropriate; they are followed by items which will enable you to indicate your accomplishment.

All objectives in this course are *learning* objectives and items are *teaching* items. They point out important things, they assist in learning, and they should enable you to do a better job for the Navy.

This self-study course is only one part of the total Navy training program; by its very nature it can take you only part of the way to a training goal. Practical experience, schools, selected reading, and the desire to accomplish are also necessary to round out a fully meaningful training program.

Learning Objective: Identify skill requirements and NEC's applicable to the Construction Mechanic rating.

1-1. A general rating is used to identify a/an

1. individual's job qualifications
2. specialty used in wartime
3. broad field of related duties
4. individual's performance

1-2. How is the NEC coding system used?

1. To facilitate management control over enlisted skills
2. To identify billets and personnel
3. To insure maximum skill utilization
4. Each of the above

In items 1-3 through 1-6, select from column B the title and NEC code described in column A.

A. Description	B. Title and NEC Code
1-3. Adjust, analyze, and repair automotive, materials handling, and construction equipment electrical systems	1. Automatic Transmission/Hydraulic Systems Mechanic, CM-5801
1-4. Maintain, repair, adjust, and overhaul diesel engines over 600 horsepower	2. Automotive Electrical Technician, CM-5802
1-5. Troubleshoot, dismantle, repair, and reassemble torque converter	3. Stationary Diesel Engine Mechanic, CM-5804
1-6. Diagnose and repair malfunctioning hydraulic pumps, valves, cylinders, and rams	

Learning Objective: Indicate some possible duty assignments for a Construction Mechanic.

1-7. As a CM you probably will never be assigned duty to

1. an amphibious construction battalion
2. a ship's company
3. a detachment of a naval mobile construction battalion
4. the fleet construction force

1-8. As a rated Construction Mechanic in a naval mobile construction battalion, you will be assigned to

1. A company
2. B company
3. C company
4. D company

1-9. If you were assigned duty to a shore activity, you would most likely be assigned to the

1. construction battalion maintenance unit
2. construction force headquarters
3. public works department
4. regimental headquarters

1-10. Assume you have been assigned shore duty at a station which has a fully staffed public works department. To which of the following jobs could you be assigned?

1. Master-at-arms force
2. Special services
3. Salvage yard
4. Each of the above

Learning Objective: Explain factors relating to qualifying and preparing for advancement.

1-11. Up-to-date changes in the Navy advancement system may be found in what publication?

1. NAVPERS 18068
2. NAVEDTRA 10653-F
3. BUPERS Notice 1418
4. BUPERS Notice 3607/1

1-12. Which of the following requirements for advancement may be waived if you have completed an appropriate Navy school?

1. Recommendation by the commanding officer
2. Length of time in pay grade required for advancement
3. Completion of the appropriate NRCC
4. Passing of a military/leadership examination

1-13. Military/leadership examinations are based on

1. occupational standards
2. professional experience
3. naval standards
4. personal knowledge

● In answering items 1-14 through 1-17, refer to textbook figures 1-1 and 1-2.

1-14. Which of the following is a requirement for an active duty Constructionman who is seeking to advance to E4?

1. Class A schooling
2. Eight years total service
3. Three years of service in grade
4. Recommendation of commanding officer

1-15. Which of the following is a requirement for advancement from CM3 to CM2 for a Construction Mechanic on active duty?

1. Serve 12 months in grade
2. Complete class B school
3. Serve a total of 8 years
4. Serve a total of 48 months at sea

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1-16. Authorizations for advancement of active duty personnel from E3 to E4 or from E4 to E5 are issued by which of the following?

1. Commanding officers
2. District commandants
3. NAVEDTRAPRODEVCEN
4. Bureau of Naval Personnel

1-17. In meeting advancement requirement of 14 days of total training duty in grade, a CM3 on inactive duty may substitute active duty time.

1-18. Of the following factors, which is used to select from persons qualified those who will be advanced?

1. Examination score
2. Length of time in service
3. Performance evaluation
4. Each of the above

1-19. When only a few vacancies are to be filled from a large number of candidates, which of the following factors determines who will be advanced?

1. Final multiple
2. Professional knowledge
3. Performance evaluation
4. Seniority among candidates

Learning Objective: Indicate sources of information and study practices that will assist the Construction Mechanic in professional development.

In answering items 1-20 through 1-22, select the publication from column B that is a source of the information in column A.

	A. Information		B. Publications
1-20.	Requirements for enlisted skills applicable to each rate within the CM rating	1.	Manual of Navy Enlisted Manpower and Personnel Classifications and Occupational Standards
1-21.	Publication number and title of the latest edition of a given Navy training manual	2.	Bibliography for Advancement Study
1-22.	Title of references used for source material for advancement examinations	3.	Naval Training Bulletin
		4.	List of Training Manuals and Correspondence Courses

1-23. The naval standards published in the Manual of Enlisted Manpower and Personnel Classifications and Occupational Standards are requirements that apply to which of the following?

1. One particular rating only
2. The CM rating only
3. Shipboard ratings only
4. All ratings

1-24. When preparing for the CM2 Navy-wide advancement examination, a CM3 should expect to be tested on the occupational standards for

1. CM2 and CM1 only
2. CM3, CM2, and CM1
3. CN, CM3, and CM2
4. CM2 only

1-25. What section of the Personnel Advancement Requirement (PAR) for CM's deals primarily with an individual's ability to perform prescribed tasks?

1. I
2. II
3. III

1-26. How often is the Bibliography for Advancement Study (NAVEDTRA 10052) revised?

1. Quarterly
2. Semiannually
3. Annually

1-27. Which of the rate training manuals listed in NAVEDTRA 10052 for your rating must you complete to become eligible to take the Navy-wide advancement examination?

1. All manuals listed for the Occupational Field 13
2. All manuals listed for the next higher rate
3. Asterisked manuals listed for the next higher rate
4. Unmarked manuals listed for the next higher rate

1-28. Before studying your rate training manual, you should study the occupational standards for Construction Mechanics.

1-29. Which of the following hints for studying should help you get the most from your Navy training course?

1. Devote your time exclusively to important military topics
2. Try not to cover a complete unit in any one study period
3. Omit easy material; study only the most difficult and the unfamiliar
4. Make notes as you study, particularly of the main ideas, then review your notes

1-30. A reliable indication that you have mastered the subject matter from a chapter in a Navy training course is your ability to

1. express in your own words the main points of the subject
2. quote word for word passages from the chapter
3. memorize pertinent dates, tables of weights and measures, and other facts
4. ask intelligent questions about the subject

1-31. You can keep abreast of new developments that affect you, your work, and the Navy by being able to

1. collect personal copies of pertinent technical manuals
2. complete all enlisted correspondence courses that pertain to your rating
3. find up-to-date information and check that which pertains to your rating
4. complete all enlisted correspondence courses that pertain to the construction ratings

1-32. To insure that the Naval Facilities Engineering Command publications that you are using are up-to-date, you should consult ________A________.
NAVFAC P-349 or DA PAM 310-4
This publication is updated
________B________.
annually or semiannually

1. (A) NAVFAC P-349; (B) annually
2. (A) NAVFAC P-349; (B) semiannually
3. (A) DA PAM 310-4; (B) annually
4. (A) DA PAM 310-4; (B) semiannually

Learning Objective: Recognize operating principles of an internal combustion engine and indicate various parts of this engine.

1-33. An internal combustion engine is a machine that

1. uses heat to create mechanical energy
2. converts heat energy to mechanical energy
3. converts mechanical energy to heat energy

1-34. What forces the piston downward during operation of a gasoline engine?

1. Compression of the fuel-air mixture
2. Intake of the fuel air-mixture
3. Expansion of the heated gases
4. Exhaust of the waste gases

1-35. Reciprocating motion is changed to rotary motion in the combustion engine by means of a

1. piston pin and a connecting rod
2. flywheel and a crankshaft
3. cylinder and a piston
4. crankshaft and a connecting rod

1-36. Which of the following basic parts are included in the 1-cylinder engine?

1. Cylinder, camshaft valve, piston, piston pin, connecting rod, and crankshaft
2. Cylinder, valve, piston, piston pin, connecting rod, and crankshaft
3. Cylinder, piston, piston pin, connecting rod, and crankshaft
4. Cylinder, piston, connecting rod, and crankshaft

1-37. What is the ratio of crankshaft revolutions to piston strokes in a 1-cylinder engine?

1. 1 to 1
2. 2 to 1
3. 1 to 2
4. 4 to 2

1-38. The movement of the intake and exhaust valves of an internal combustion engine is controlled by the

1. balance shaft
2. camshaft
3. connecting rod
4. crankshaft

1-39. Which of the following events occurs during the second stroke in the sequence of strokes for the 4-stroke cycle engine?

1. The piston moves downward
2. The waste gases are exhausted
3. The air-fuel mixture is compressed
4. The air-fuel mixture is ignited

1-40. At what point in the cycle of a 4-stroke cycle engine does ignition occur?

1. Beginning of the compression stroke
2. End of the compression stroke
3. Beginning of the intake stroke
4. During the power stroke

1-41. During which stroke in the operating cycle of a 4-stroke cycle engine is the greatest force exerted on the piston head?

1. Intake
2. Compression
3. Power
4. Exhaust

In items 1-42 through 1-44, select from column B the combination of piston movement and valve conditions that occurs during the basic engine stroke in column A.

	A. Strokes	B. Piston Movements and Valve Conditions
1-42.	Compression	1. Piston moving up; exhaust valve open, intake valve closed
1-43.	Power	2. Piston moving up; exhaust and intake valves closed
1-44.	Exhaust	3. Piston moving down; intake valve open, exhaust valve closed
		4. Piston moving down; exhaust and intake valves closed

1-45. In what order do the strokes of a 4-stroke cycle engine occur during operation?

1. Compression, power, exhaust, intake
2. Compression, power, intake, exhaust
3. Intake, compression, power, exhaust
4. Intake, compression, exhaust, power

1-46. A piston in a 4-stroke cycle engine makes four strokes during each

1. crankshaft revolution
2. engine cycle
3. period of two combustion cycles
4. cycle of two events

1-47. Which of the following statements is TRUE concerning the operating cycle of a 2-stroke cycle diesel?

1. The exhaust valves and intake ports are never open at the same time
2. The exhaust valves remain open until the piston reaches top dead center
3. The inlet ports are uncovered after the exhaust valves open
4. The inlet ports are uncovered when the piston reaches bottom dead center

1-48. By what means are burned gases cleared from the cylinder of the 2-stroke cycle diesel engine?

1. Air forced into the cylinder
2. Upward motion of the piston
3. Both 1 and 2 above
4. Scavenging effect caused by the piston

1-49. Which of the following reasons partially accounts for the failure of a 2-stroke cycle engine to produce twice the power of a 4-stroke cycle engine of the same size?

1. Some power developed by the 2-stroke cycle engine is used to force air and fuel into each cylinder
2. Less than all the combustion gases are scavenged from each cylinder of the 2-stroke cycle engine
3. For a given air-fuel mixture, less fuel and air enter the cylinders of the 2-stroke cycle engine
4. Each of the above

1-50. Which of the following is an advantage of the multicylinder engine over the single-cylinder engine?

1. More efficient
2. Smoother power
3. Higher speeds
4. Fewer moving parts

1-51. The flywheel of an engine affects the operation of the engine by

1. smoothing out the power impulses
2. keeping the engine from stalling
3. preventing crankshaft vibration
4. increasing piston life

1-52. How are engines most commonly classified?

1. By their valve arrangements
2. By the number of their cylinders
3. By the kind of fuel they burn
4. By their cooling systems

1-53. All multicylinder gasoline engines are alike in that each engine is equipped with a/an

1. carburetor and spark plugs
2. intake manifold and preheaters
3. blower and inlet ports
4. injection pump and injectors

1-54. If the firing order is not marked on a engine and a manufacturer's manual is not available, what method should you use to find the engine's firing order?

1. Crank the engine by hand, observing the order in which the exhaust valves open
2. Crank the engine by hand while observing the timing mark on the crankshaft
3. Crank the engine with the starter and observe the rotor in the distributor
4. Crank the engine by hand and observe the order in which the intake valves open

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In items 1-55 through 1-57, select from column B the letter designation for the internal combustion engine that uses the valve arrangement in column A.

	A. Valve Arrangements	B. Letter designations
1-55.	Intake and exhaust valves in block on same side of cylinder	1. F-head
		2. L-head
1-56.	Intake valves in the head and exhaust valves in block	3. I-head
		4. T-head
1-57.	Intake and exhaust valves in the head	

Learning Objective: Describe fundamentals of measuring engine performance.

1-58. What are the definitions of torque, energy, and power--in that order?

1. Turning force; capacity to do work; rate of doing work
2. Turning force; rate of doing work; capacity to do work
3. Rate of doing work; turning force; capacity to do work
4. Rate of doing work; capacity to do work; turning force

1-59. The inertia possessed by a truck traveling straight ahead at 25 miles per hour is defined as the

1. effect that the force of gravity has on the truck when its heading is changed
2. resistance that the atmosphere offers the truck at 25 miles per hour
3. tendency of the truck to keep moving straight ahead at 25 miles per hour
4. effort which the truck's engine applies to keep the truck moving at 25 miles per hour

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When answering items 1-60 through 1-62, select from column B the definition of the term in column A.

	A. Terms	B. Definitions
1-60.	Mechanical efficiency	1. The relationship between the power output of an engine and the energy in the fuel burned to produce this output
1-61.	Thermal efficiency	
1-62.	Volumetric efficiency	
		2. The relationship between the power developed within an engine and the power delivered by the engine
		3. The relationship between the theoretical and actual power input of an engine
		4. The relationship between the amount of fuel-air mixture that enters an engine cylinder and the amount that could enter

1-63. What is the meaning of the cylinder designation 3 1/4 by 3 1/2 inches?

1. Piston stroke is 3 1/4 inches; cylinder bore is 3 1/2 inches
2. Cylinder diameter is 3 1/4 inches; TDC-to-BDC distance in the cylinder is 3 1/2 inches
3. Cylinder bore is 3 1/4 inches; piston head diameter is 3 1/2 inches
4. Piston stroke is 3 1/4 inches; piston head diameter is 3 1/2 inches

1-64. The compression ratio of an engine is determined by

1. subtracting the cylinder volume at TDC from the cylinder volume at BDC
2. dividing the cylinder volume at TDC by the cylinder volume at BDC
3. multiplying the cylinder volume at TDC by the length of the piston stroke
4. dividing the cylinder volume at BDC by the cylinder volume at TDC

1-65. Increasing the compression ratio of an engine will result in

1. higher engine speed
2. more power
3. less cylinder wear
4. higher fuel consumption

1-66. Valve timing refers to the relationship between the position of the valves and the

1. length of time the valves are closed
2. number of cycles in the engine
3. length of time the valves are open
4. position of the pistons in the cylinder

1-67. Ignition timing should be adjusted so that the spark occurs when the piston does which of the following?

1. Completes the intake stroke
2. Starts down on the power stroke
3. Completes the compression stroke
4. Nears the end of the compression stroke

Assignment 2

Internal Combustion Engines -- Construction

Textbook, NAVEDTRA 10644-G: Pages 28 -58

Learning Objective: Recognize operating principles of the stationary and moving parts of an internal combustion engine.

2-1. Gasoline and diesel engines are alike in what respect?

1. Both belong to the same engine family
2. Both have the same basic internal components
3. Both have the same number of cylinders
4. Their internal parts are interchangeable

2-2. The function of an engine's stationary parts is to

1. add power to the engine
2. keep the engine firmly attached to its supporting base
3. furnish a framework on which to attach or enclose movable parts
4. regulate crankshaft speed

2-3. Which of the following parts provides a basic frame for the water-cooled engines used in automotive and construction equipment?

1. Engine base
2. Cylinder head
3. Cylinder block
4. Crankcase

2-4. What is the purpose of the interconnecting passages in the cylinder head and block?

1. To allow access for removal of the casting material
2. To provide a path for the coolant to circulate
3. To prevent cracks in the castings as they cool

2-5. The purpose of fins surrounding the cylinders of an air-cooled engine is to provide a

1. means for strengthening the cylinder walls
2. mounting place for the cylinder head
3. large surface area for heat dissipation

2-6. Cylinder liners are used in an engine to

1. prevent scoring or cracking of the cylinder walls
2. increase cylinder wear limitations
3. eliminate cylinder block replacement due to cylinder wear
4. reduce the frequency of engine overhauls

2-7. Cylinder liners are either wet liners or dry liners according to whether or not they come in contact with the coolant.

2-8. Which of the following is an indication that the cylinder liner seals are leaking?

1. Presence of air bubbles in the coolant
2. Presence of coolant in the crankcase
3. Overheating of the engine
4. High rate of oil consumption

2-9. Running a truck engine with the air cleaner removed would be likely to cause excessive

1. gas consumption
2. cylinder wear
3. knocking
4. bearing wear

2-10. The greatest amount of cylinder wall wear in an engine occurs near what point relative to piston travel?

1. Top
2. Midpoint
3. Bottom

2-11. Which of the following is a reason that some large diesel engines are manufactured with separated cylinder heads instead of one head for all cylinders?

1. It costs less to replace separated heads
2. It takes less work to tear down engines having separated heads
3. Separated heads do not warp as easily
4. Each of the above

2-12. One reason that engine cylinder heads are made of aluminum alloy is the ability of the alloy to

1. resist wear
2. resist corrosion
3. retain its shape
4. conduct heat

2-13. The curved surfaces of the pockets in which the valves of an L-head type cylinder head function are designed for the purpose of

1. shortening the compression stroke
2. lengthening the compression stroke
3. decreasing the turbulence of the fuel-air mixture
4. increasing the turbulence of the fuel-air mixture

2-14. The I-head type of cylinder head differs from the L-head in what respect?

1. It has smaller coolant passages
2. It has openings for the spark plugs
3. It contains all the valve operating mechanisms
4. It contains part of the combustion chamber

2-15. The crankcase is that part of the engine block above the cylinders.

2-16. The stationary part of an internal combustion engine that carries waste products of combustion from the cylinders is called the

1. intake manifold
2. exhaust manifold
3. carburetor
4. water pump

2-17. Why is it desirable that the intake manifold of a gasoline combustion engine be constructed so as to provide the fuel with a short and direct path between the carburetor and the cylinder?

1. To make the fuel-air mixture as uniform as possible
2. To save space in the engine compartment
3. To reduce the possibility of the fuel condensing in the manifold
4. To keep the manifold from overheating

2-18. Which of the following features is common to all engines equipped with an exhaust gas recirculation system?

1. They have an intake manifold with exhaust passages
2. Each cylinder contains two intake valves
3. Each cylinder contains an exhaust valve and an exhaust port
4. The exhaust valves are open during the intake strokes

2-19. A gasket is placed between the cylinder head and engine block to

1. prevent gas and water leaks
2. provide even heat distribution
3. maintain clearance between the cylinder head and the engine block
4. prevent excessive temperatures within the cylinder head

2-20. From what material are the gaskets of intake and exhaust manifolds usually constructed?

1. Press paper
2. Pressed cork
3. Asbestos
4. Soft metal

2-21. What type of material are oil pan gaskets usually made of?

1. Oil resistant paper
2. Cork
3. Asbestos

2-22. In today's engines, fluid losses through clearances between moving parts and stationary parts are prevented by means of

1. neoprene seals and O-rings
2. leather seals
3. packing glands
4. plastic strips

2-23. Heat energy is changed to mechanical energy in an engine by the pressure from combustion acting on the

1. connecting rods
2. camshaft
3. flywheel
4. pistons

2-24. The downward motion of the piston in the cylinder is converted to rotary motion by the action of the

1. gear train
2. camshaft
3. connecting rod and crankshaft
4. valves

2-25. The design of which of the following engine parts enables them to create an effect inside the combustion chambers that results in an improved fuel-air mixture?

1. Cylinder walls
2. Pistons
3. Exhaust valves
4. Connecting rods

2-26. What principal difference exists between a diesel engine piston and a gasoline engine piston?

1. Diesel engine pistons weigh less than gasoline engine pistons
2. Diesel engine pistons are made of cast iron while gasoline engine pistons are made of aluminum
3. Diesel engine pistons are usually fitted with more piston rings than gasoline engine pistons

2-27. Aluminum pistons will expand more than cast-iron pistons under the same operating conditions and are therefore often designed with

1. split skirts
2. full trunk skirts only
3. slipper skirts only
4. full trunk and slipper skirts

2-28. The piston pin (wrist pin) attaches the piston to the

1. crankshaft
2. camshaft
3. connecting rod
4. balance shaft

2-29. In addition to sealing off the combustion chamber and distributing lubricating oil, piston rings serve to

1. absorb the shock of the power stroke
2. prevent heat expansion of the piston
3. transfer heat from the pistons to the cylinder wall
4. provide an air bleed during the intake stroke

2-30. Piston rings are staggered during assembly to

1. allow even heat dissipation
2. reduce cylinder leakage
3. cause even cylinder wear
4. allow the use of expanders

2-31. When installed in an engine, piston rings are fitted to the piston and cylinder to insure proper end and side clearances.

2-32. During engine operation, thrust from the piston is transmitted to the crankshaft by the

1. balance shaft
2. camshaft
3. connecting rod
4. flywheel

2-33. Which of the following types of bearings is placed in the piston end of the connecting rod?

1. Roller
2. Ball
3. Bushing

2-34. Precision connecting rod bearings are held in position against a crankshaft by

1. projections on the bearing shells
2. bolts that hold the connecting rods together
3. slip fittings on the connecting rod
4. projections on the connecting rod

2-35. What is the function of the counterweights on a crankshaft?

1. To reduce shock from the power strokes
2. To balance the weight of the connecting rod bearing assembly
3. To transmit power from the crankshaft to the camshaft
4. To provide momentum for crankshaft rotation during the compression strokes

2-36. On a 6-cylinder engine, how many degrees apart are the crankshaft throws?

1. 60
2. 90
3. 120
4. 180

2-37. What part of an engine is likely to fail when subjected to uncontrolled torsional vibrations?

1. Camshaft
2. Piston
3. Connecting rod
4. Crankshaft

2-38. The purpose of thrust faces found on some main bearings is to

1. prevent crankshaft vibration
2. eliminate crankshaft end play
3. maintain connecting rod alinement
4. insure proper bearing lubrication

2-39. What bearing size will best fit a crankshaft that has been reground?

1. Standard
2. Undersized
3. Oversized

2-40. The vibration damper is a device designed to

1. balance camshaft speed with crankshaft speed
2. reduce twisting strain on the crankshaft
3. brake the flywheel during engine speed reduction
4. reduce flywheel vibration

2-41. In addition to reducing engine speed fluctuations, the flywheel often serves as a

1. power takeoff for the camshaft and a pressure surface for the clutch
2. pressure surface for the clutch and starting system gear
3. starting system gear and a power takeoff for the fuel pump
4. power takeoff for the fuel pump and a timing reference for the ignition system

2-42. The purpose of a valve-actuating mechanism is to overcome the spring pressure and open the valves at the proper time.

2-43. Which of the following components help to make up the valve-actuating mechanism?

1. Camshaft and camshaft followers (tappets)
2. Pushrods
3. Rocker arms
4. All of the above

2-44. The purpose of the camshaft is to aid in

1. holding the valves in place
2. forcing gas to the carburetor
3. operating the valve mechanism
4. rotating the valve

2-45. On which of the following types of engine heads is the camshaft usually located directly above the crankshaft?

1. L
2. F
3. I
4. V

2-46. The camshaft of a two-stroke cycle engine will rotate at what speed when the engine's crankshaft speed is 1000 rpm?

1. 250 rpm
2. 500 rpm
3. 1000 rpm
4. 2000 rpm

2-47. How is the zero clearance maintained by the hydraulic type valve lifters shown in figure 3-25 of your textbook?

1. By vacuum
2. By oil pressure
3. By cam lobe action
4. By spring pressure

2-48. An accumulation of carbon on valve seats will result in

1. increased valve life
2. cooler operating valves
3. positive valve seating
4. improper valve closure

Learning Objective: Point out techniques in valve reconditioning and timing gear installation.

2-49. What part of an engine must be removed before the valves are accessible?

1. Cylinder head
2. Exhaust manifold
3. Intake manifold

2-50. During reassembly of an engine, replacing the valves in their original guides will result in

1. excessive wear of the valve and guide
2. less valve wear
3. failure of the valve to seat properly
4. noisy valve operation

2-51. The cylinder block of an engine is normally inspected during a valve job to insure against the presence of

1. warpage
2. ridges at the top of the cylinders
3. cracks around the cylinders

2-52. The easiest method of cleaning the water passages inside a cylinder head is to

1. boil the cylinder head in a cleaning solution
2. scrape out the unwanted material
3. flush with water under pressure
4. blow out with compressed air

2-53. One procedure for checking valve guide wear involves the use of a

1. thickness gage
2. depth gage
3. hole gage and micrometer
4. valve guide gage

2-54. In grinding valve seats, you should check your work often to avoid removing too much metal.

2-55. When an unusually large amount of a valve seat is removed by grinding, the seat must be narrowed and centered by means of a

1. 45° narrowing stone
2. 20° narrowing stone and a 70° stone
3. lapping compound
4. grinding compound

2-56. Which of the following checks should you make on the valve springs before reassembling them?

1. Height
2. Strength
3. Warpage
4. Each of the above

2-57. Which of the following is a step in the procedure for installing directly driven timing gears on an engine?

1. Position the gears so that the single marked tooth of one gear is between the two marked teeth of another gear
2. Rotate two gears until their marked teeth can be alined with a straightedge
3. Install the timing chain after positioning the crankshaft and camshaft gear
4. Match the idler gears' marked teeth with those on the camshaft and crankshaft

2-58. The back of the typical bearing half is constructed of

1. cast iron
2. bronze only
3. steel only
4. steel or bronze

2-59. Oil moves across the face of a bearing in order to accomplish which of the following?

1. Cool the bearing
2. Lubricate the bearing
3. Remove dirt from the bearing
4. All of the above

2-60. What happens as oil clearance in bearings becomes greater?

1. Oil flows more quickly through the bearings
2. Oil flows more slowly through the bearings
3. Oil pressure increases
4. Bearings remain cool

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In items 2-61 through 2-63, select from column B the bearing capability that is described in column A.

A. Descriptions

2-61. Being hard and tough enough to keep from wearing fast

2-62. Able to withstand repeated stresses without failing

2-63. Able to withstand being eaten away by the byproducts of combustion

B. Bearing Capabilities

1. Embedability
2. Fatigue resistance
3. Wear rate
4. Corrosion resistance

2-64. Which of the following is an advantage of the power package concept?

1. It prevents excessive downtime of equipment
2. It eliminates the need for engine overhauling
3. It increases the number of interchangeable parts available
4. Each of the above

Assignment 3

Fuel Systems: Properties of Gasoline and Gasoline Fuel Systems

Textbook NAVEDTRA 10644-G: Pages 59 - 81

Learning Objective. Identify properties of gasoline and the operating principles of gasoline fuel systems.

3-1. When a fuel fails to evaporate readily in a cold climate, which of the following will result?

1. Hard starting
2. Loss of power
3. Increased fuel consumption
4. All the above

3-2. The percentage of heat energy developed in a gasoline engine that actually provides power at the flywheel is approximately

1. 10% to 15%
2. 20% to 25%
3. 30% to 35%
4. 40% to 45%

3-3. Detonation in the cylinders of a gasoline engine occurs before the spark plugs fire.

3-4. Which of the following additives is used to improve the anti-knock quality of a gasoline?

1. Ethyl fluid
2. Ethyl chloride
3. Tetraethyl lead
4. Ethylene glycol

3-5. Which of the following will result when engine ignition timing is retarded beyond the manufacturer's specifications to compensate for low-octane fuel?

1. Overheating
2. Less fuel consumption
3. Improved performance
4. Burned valves

3-6. In addition to low-octane fuel, which of the following conditions can cause an engine to knock?

1. Preignition
2. Lean fuel mixture
3. Faulty cooling system
4. Each of the above

3-7. The fuel system provides the engine cylinders with which of the following?

1. Raw gases
2. A mixture of gasoline vapor and air
3. A mixture of gasoline and vapor
4. All of the above

3-8. If a warm engine is operating at a normal rate of speed, how many pounds of air should be mixing with every 2 pounds of gasoline used?

1. 15 pounds
2. 30 pounds
3. 45 pounds
4. 60 pounds

3-9. Under which of the following conditions would you need a mixture richer than 15 pounds of air to 1 pound of gasoline?

1. When starting a cold engine
2. When accelerating
3. When operating at a high speed or operating with a full load
4. All of the above

3-10. In a gasoline engine equipped with a fuel injection system, the fuel is injected into the

1. cylinders
2. intake manifold
3. intake passages of the cylinder head

3-11. A mixture consisting of 9 pounds of air and 1 pound of gasoline is richer than one consisting of 18 pounds of air and 1 pound of gasoline.

3-12. Which feature of a gasoline tank prevents sediment from entering the remainder of the fuel system?

1. Position of the outlet pipe
2. Arrangement of the baffles
3. Design of the outer shell
4. Location of the filter

3-13. What is the function of the baffle plates found in the gasoline tank?

1. To reinforce the bottom of the gasoline tank
2. To reinforce the sides of the gasoline tank
3. To prevent the fuel from surging or splashing
4. All of the above

3-14. The function of the fuel pump is to

1. measure the amount of gas that enters the carburetor
2. deliver the fuel requirements of the engine
3. pump gas from the carburetor to the intake manifold
4. pump gas from the carburetor through the gasoline filter into the manifold

3-15. Which of the following conditions is a symptom of a vehicle that has low fuel-pump pressure?

1. The carburetor float needle being held off its seat
2. An increase in gasoline consumption
3. Air locks in the fuel lines
4. Each of the above

3-16. To check the output of a fuel pump, which of the following test devices is normally used?

1. Pressure gage
2. Flow meter
3. Manometer
4. Vacuum gage

3-17. What component maintains the proper pressure in the line between the fuel pump and the carburetor?

1. Fuel filter
2. Fuel gage
3. Fuel pump
4. Sediment bowl

3-18. The carburetor of a gasoline engine receives fuel from the fuel pump only when the

1. pressure maintained in the diaphragm spring of the pump is less than the fuel pressure in the outlet
2. pressure maintained by the diaphragm spring of the pump is greater than the fuel pressure in the outlet
3. fuel passage from the pump is open into the float chamber and the float needle valve is seated
4. fuel passage from the pump is closed and the float needle valve of the carburetor is unseated

3-19. What type of fuel pump delivers fuel continuously regardless of the demand for it?

1. Autopulse
2. Positive diaphragm
3. Nonpositive diaphragm
4. Diaphragm

3-20. Which of the following pumps will deliver fuel only when the float valve in the carburetor is opened?

1. Positive diaphragm
2. Nonpositive diaphragm
3. Electric tank unit
4. Diaphragm

3-21. What type of fuel pump starts to function when the ignition switch is turned on?

1. Diaphragm
2. Positive diaphragm
3. Nonpositive diaphragm
4. Autopulse

3-22. Which device insures positive operation of vacuum type windshield wipers at all times?

1. Fuel pump with a vacuum booster
2. Electrical fuel pump
3. Single action fuel pump
4. Double action fuel pump

3-23. Which type of fuel line fitting is used most often with gasoline fuel systems?

1. Compression
2. Soldered
3. Flared

3-24. Which of the following conditions is most likely to lower the speed with which the molecules of a liquid escape as vapor?

1. Raising the temperature of the liquid
2. Removing evaporated particles from the air above the liquid
3. Decreasing air pressure at the surface of the liquid
4. Lowering the temperatures of the liquid

3-25. The purpose of the venturi passage in a carburetor is to

1. lower the atmospheric pressure in the float bowl to force the gasoline through the fuel outlet nozzle
2. create a partial vacuum to permit atmospheric pressure to force the fuel from the float bowl
3. reduce the rate of vaporization by lowering the pressure of the air entering the carburetor
4. spray the fuel in the air by increasing the speed of the air entering the carburetor

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In items 3-26 through 3-28, select from column B the control or circuit that causes the carburetor to perform the function in column A.

	A. Functions	B. Controls or Circuits
3-26.	Enrich the mixture when the throttle is suddenly opened	1. Accelerating 2. Maximum power or full load
3-27.	Supply an enriched mixture when the engine is operating at a minimum speed	3. Idling 4. Throttle
3-28.	Enrich the mixture when the throttle is opened wide	

3-29. The component that varies the amount of fuel-air mixture that enters the intake manifold is the

1. automatic choke
2. fuel pump
3. throttle valve
4. venturi

3-30. The fuel supply in the carburetor bowl is controlled by the

1. throttle
2. fuel pump
3. choke
4. float

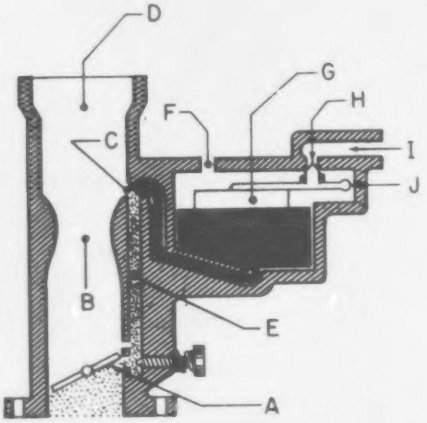

Figure 3A.

- In answering items 3-31 through 3-34, refer to figure 3A.

3-31. The idle and low-speed circuit is identified by what letter?

1. A
2. C
3. E
4. G

3-32. Atmospheric pressure which forces fuel down through the idle circuit is admitted to the carburetor at

1. F
2. H
3. I
4. J

3-33. At what place in the carburetor does the gasoline start to atomize?

1. A
2. B
3. C
4. D

3-34. When more fuel is needed to support low-speed operation, the position of the low-speed port will be such that it is just below the edge of

1. A
2. C
3. E
4. G

3-35. In its high speed circuit, a carburetor maintains a fairly constant ratio of fuel to air and, though an enriched mixture is produced, prevents overrichness by

1. decreasing the volume of air through the venturi
2. maintaining a constant volume of air in the venturi and causing fuel to discharge from the nozzle
3. letting more air enter the main nozzle

3-36. Which of the following air-to-fuel carburetor ratios by weight will normally produce the most power in the high speed circuit?

1. 12:1
2. 13:1
3. 14:1
4. 15:1

3-37. Which of the following carburetor components is designed to increase engine power but still maintain reasonable economy?

1. Power jet
2. Metering rod
3. Vacuum step-up
4. All of the above

3-38. What carburetor component determines the amount of fuel that the power jet will supply?

1. Throttle
2. Float
3. Power-jet valve
4. Vacuum-actuated piston

3-39. To insure delivery of the proper fuel-air mixture for all operating conditions, each position of the throttle valve must be synchronized with the position of the

1. power jet
2. metering rod
3. vacuum step-up
4. venturi

3-40. Which carburetor component provides sufficient fuel to accelerate quickly?

1. Power jet
2. Accelerating pump circuit
3. Metering rod
4. Vacuum-actuated piston

3-41. What is the function of the intake check valve in the accelerating pump circuit?

1. To permit a supply of fuel to reach the cylinder
2. To prevent fuel in the cylinder from being pushed back into the bowl
3. Both 1 and 2 above
4. To prevent the accelerating jet flow from flowing at constant throttle openings

3-42. What component of the accelerating pump circuit meters the amount of fuel used?

1. A lever on the throttle shaft
2. A discharge check valve
3. An intake check valve
4. An accelerating jet

3-43. Which of the following components aids a a vacuum-actuated pump plunger in moving downward in the cylinder when the throttle is open?

1. Linkage with the throttle
2. Accelerator pump spring
3. Accelerator jets
4. Low vacuum in the venturi

3-44. What is the function of the air-vent check valve in the accelerating pump circuit?

1. To prevent the accelerating jet flow from flowing at constant throttle openings
2. To allow air to enter the passage connecting the pump cylinder and accelerating jet
3. To prevent fuel from being discharged back into the bowl through the air-vent passage
4. All of the above

3-45. A delayed action is basic to the operation of the accelerating pump circuit of the carburetor in that it provides a continuous stream of fuel from the pump jet after the throttle has ceased moving.

3-46. A choke alters the air-fuel mixture that enters the manifold of a cold gasoline engine during starting by admitting

1. less air
2. more air
3. less fuel and more air
4. more fuel and more air

3-47. What component in the choke circuit needs the assistance of a coiled spring on the end of the choke shaft and pressure to operate properly?

1. Springloaded poppet valve
2. Off-center choke valve
3. Needle valve
4. Power jet

3-48. Of the following factors, which affects the operation of the automatic choke?

1. Heat
2. Intake manifold vacuum
3. Velocity of air passing through the air horn
4. All of the above

3-49. In the operation of an automatic choke, helping to close the choke valve and holding it closed are functions of the

1. low intake manifold pressure
2. thermostatic spring
3. hot air from the exhaust manifold
4. velocity of the air passing through the carburetor air horn

3-50. Failure of the automatic choke illustrated in textbook figure 4-22 can often be attributed to

1. carbon in the exhaust gases
2. rapid deterioration of the coil spring
3. wear and binding of the choke shaft
4. vacuum leaks at the vacuum piston

3-51. Which of the following troubles within the carburetor system will cause an engine to use an excessive amount of fuel?

1. High float level
2. Defective radiator thermostat
3. Air leaking into the intake manifold
4. A weak accelerator spring

3-52. An engine that uses an excessive amount of fuel could have which of the following problems?

1. A sticking metering rod or full power piston
2. A sticking accelerating pump
3. Too rich an idling mixture
4. Each of the above

3-53. Which of the following troubles within the carburetor system will cause an engine to perform sluggishly?

1. Defective choke
2. Improperly adjusted throttle link
3. Sticking high-speed piston
4. A loose air cleaner

3-54. A dirty fuel passage or a clogged air cleaner could cause an engine to

1. fail to start
2. have a smoky black exhaust
3. backfire
4. perform sluggishly

3-55. Which of the following conditions will most likely cause an engine to idle poorly?

1. Too rich idle mixture
2. Defective choke
3. Incorrectly adjusted idle speed screw at the throttle valve
4. Each of the above

3-56. A plugged fuel line would cause an engine

1. to idle poorly
2. to stall as it warms up
3. not to start
4. to run slowly

3-57. Assume that an engine is hard to start once it has warmed up. What is the problem?

1. A leaky float
2. Defective or improperly adjusted carburetor unloader linkage
3. Defective radiator thermostat
4. Weak fuel pump

3-58. Which of the following conditions will make an engine slow about warming up?

1. Rich air-fuel mixture
2. Improperly adjusted throttle link
3. Defective radiator thermostat
4. Leaking fuel pump

3-59. Which of the following conditions within the carburetor system will cause an engine to emit smoky, black exhaust?

1. Low float level
2. Defective radiator thermostat
3. Dirty or gummy fuel passages
4. Very rich air-fuel mixture

3-60. A defective choke or closed choke valve could cause an engine to

1. stall as it warms up
2. backfire
3. overheat

3-61. Which of the following conditions within the carburetor system could cause an engine to backfire?

1. Incorrect air-fuel mixture reaching the engine
2. Clogged fuel lines
3. Fluctuating fuel level
4. Each of the above

3-62. Why are air cleaners used on all internal combustion engines?

1. To protect the carburetor from excessive wear
2. To keep dust and other foreign matter out of the engine
3. To lower the moisture content of the air entering the engine
4. To eliminate carburetor icing on humid days

3-63. Why is the dry-type air cleaner preferable to the wet-type?

1. It requires less maintenance
2. It aids in conserving petroleum
3. It is more efficient

3-64. Which of the following functions is performed by the intake manifold?

1. Admitting outside air to the air cleaner
2. Providing an air passage between the air cleaner and carburetor
3. Forming a passage for the air-fuel mixture to enter the engine's cylinders
4. Passing air from the engine to the muffler

3-65. The intake manifold is mounted on the side of the cylinder head on which of the following engines?

1. L-head
2. I-head
3. V-8
4. All of the above

3-66. Why is the carburetor mounted at the center of the intake manifold?

1. To facilitate maintenance
2. To insure that an adequate supply of air can enter the carburetor
3. To reduce the tendency of carburetor icing
4. To insure even distribution of the air-fuel mixture

3-67. When the carburetor or manifold gasket is NOT seated properly, which of the following will result?

1. Reduced engine compression
2. Overheated exhaust
3. Lean fuel mixture at one or more cylinders
4. Black smoky exhaust

3-68. The purpose of the exhaust manifold is to

1. take air from the inside to the air filter
2. allow used gases to pass from the engine cylinders
3. pass air from the filter to the carburetor
4. pass air and fuel from the carburetor to the engine

3-69. An exhaust manifold is attached to each bank of cylinders on which of the following engines?

1. L-head
2. I-head
3. V-8
4. All of the above

3-70. What is the purpose of the manifold heat valve?

1. To create a "hot spot" around the exhaust manifold
2. To run the windshield wipers in case the manifold vacuum is insufficient
3. To heat the air-fuel mixture in cold weather until the engine warms up
4. To provide additional heat inside the vehicle in cold weather

3-71. When the manifold heat control valve sticks, which of the engine's internal parts will be damaged?

1. Exhaust valves
2. Intake valves
3. Pistons
4. Piston rings

3-72. Which of the following lubricants is recommended for use on the manifold heat control valve?

1. Dry-stick lubricant
2. Graphite mixed with penetrating oil
3. Chassis grease
4. Medium grade engine oil

3-73. Which of the following factors is an indication of a clogged muffler?

1. Engine not developing maximum power
2. Difficulty in starting
3. Engine operating at a higher than normal temperature
4. Each of the above

3-74. For which of the following reasons would you install a rain cap on a vehicle?

1. To protect the operator
2. To prevent the rain and dirt from entering the engine
3. To keep the engine dry

3-75. In tuning up an engine which has emission control devices, you must use the specifications for that engine to insure the devices function properly.

Assignment 4

Fuel Systems (continued): Properties of Diesel Fuel and Diesel Fuel Systems

Textbook, NAVEDTRA 10644-G: Pages 81 - 121

Learning Objective: Identify properties of diesel fuel, operating principles of diesel fuel systems, and techniques of servicing fuel system components.

4-1. What makes it possible to ignite the fuel-air mixture of a diesel engine without the use of a spark as in a gasoline engine?

1. The ignition temperature of diesel fuel is low
2. The compression ratio of the diesel engine is low
3. The compression temperature of the diesel engine is high
4. The speed of the diesel engine's moving parts is high

4-2. How is the speed of a diesel engine controlled?

1. By regulating the amount of fuel delivered to the engine's cylinders
2. By altering the compression pressure within the engine's cylinders
3. By changing the volume of air entering the cylinders
4. By limiting the capacity of the fuel injection system

4-3. Which of the following characteristics is one advantage of the diesel engine over the gasoline engine?

1. Low production cost
2. Suitability for vehicles transporting small loads
3. Smoothness of operation
4. High ratio of power output to fuel consumed

4-4. Which of the following items is considered a disadvantage of the diesel engine as compared to the gasoline engine?

1. High cost of manufacture
2. Heavier construction necessary to withstand the high compression pressures
3. Difficulty in starting
4. Each of the above

4-5. Which of the following sequences of events characterizes the operation of a diesel engine?

1. The fuel and air are mixed, the partly vaporized mixture enters on the intake stroke, and a spark ignites it near the end of the compression stroke
2. The fuel and air are mixed, the mixture enters on the compression stroke, and a spark ignites it near the end of the compression stroke
3. The air enters on the intake stroke, the fuel is injected near the end of the compression stroke, and the high temperature ignites the fuel
4. The fuel enters on the intake stroke, the air is injected under pressure near the end of the compression stroke, and the high temperature ignites the fuel

4-6. What effect would a diesel fuel with poor lubricating qualities have on the operation of a diesel engine?

1. Excessive fuel consumption
2. Gradual decrease in the injection system's efficiency
3. Hot smoky exhaust gases
4. Rapid cylinder wear

4-7. Which of the following characteristics of diesel fuel creates the need for better filtering than that required for gasoline?

1. Viscosity
2. Ignition quality
3. Volatility

4-8. The cetane value of a diesel fuel is a measure of its

1. volatile characteristics
2. antiknock qualities
3. ignition qualities
4. viscosity characteristics

4-9. Which of the following combustion chamber designs requires the highest fuel injection pressure?

1. Open
2. Precombustion
3. Turbulence chamber
4. Hypercycle

4-10. When precombustion chambers are used on a diesel engine, which of the following factors causes the greatest amount of fuel atomization?

1. Turbulence within the cylinders
2. High fuel injection pressure
3. Dispersion of fuel from the multi-orifice fuel injectors
4. Rapid air movement within the precombustion chamber

4-11. What effect, if any, does using JP-4 as fuel in the multifuel engine have on its operation?

1. Decreases engine life
2. Produces too much exhaust smoke
3. Increases power
4. None

4-12. Which of the following components is designed to prevent an engine from overspeeding, but allows the engine to meet changing load conditions?

1. Fuel pump
2. Carburetor
3. Throttle valve
4. Governor

4-13. Where is the governor connected on a diesel engine?

1. Next to the fuel pump
2. Between the throttle and the fuel injector
3. Between the fuel pump and the fuel filter
4. Between the carburetor and the fuel filter

4-14. Which of the following factors is used to classify governors used on diesel engines?

1. The method by which the governor operates the fuel control mechanism
2. The forces which act on the governor and cause it to operate
3. The function for which the governor is designed to perform
4. Each of the above

4-15. A chief factor in the selection of the governor for a diesel engine is

1. total piston displacement
2. rated horsepower
3. type of load
4. maximum engine speed

In items 4-16 through 4-19, select from column B the type of governor that best fits the function in column A.

	A. Functions	B. Governors
4-16.	Provides a regular or stable engine speed, regardless of load conditions	1. Constant-speed governor 2. Variable-speed governor
4-17.	Prevents an engine from exceeding a specified maximum speed	3. Speed-limiting governor
4-18.	Maintains any specified engine speed between idle and maximum	
4-19.	Prevents an engine from dropping below specified minimum speed	

4-20. What part of a spring-loaded centrifugal governor does the manual throttle directly adjust?

1. Linkage between flyballs and injectors
2. Spring tension
3. Position of flyballs
4. Centrifugal-force generator

4-21. The tension of the spring in the spring-loaded centrifugal governor has a tendency to do which of the following?

1. Stabilize the amount of fuel delivered to the cylinders
2. Reduce the amount of fuel delivered to the cylinders
3. Increase the amount of fuel delivered to the cylinders
4. Each of the above

4-22. For engine speed to stabilize, what must occur within the governor?

1. Centrifugal force must overcome spring tension
2. Spring tension must overcome centrifugal force
3. Centrifugal force and spring tension must balance fuel supply pressure
4. Centrifugal force and spring tension must be equalized

4-23. What will happen, within the governor, when the load on an engine is reduced and the engine speed increases?

1. The centrifugal force becomes greater than the spring tension
2. The centrifugal force becomes lesser than the spring tension
3. The centrifugal force remains the same
4. The centrifugal force acts on the fuel control linkage to increase the amount of fuel delivered to the cylinders

4-24. A simple mechanical governor can be distinguished from a simple hydraulic governor by the presence of a

1. mechanical linkage between the governing unit and the fuel-control mechanism
2. set of two rotating weights
3. spring device
4. sensitivity control

4-25. When faulty governor operation allows an engine to overspeed, which of the following procedures should you use to stop the engine?

1. Repair the governor and then secure the engine
2. Shut off the fuel supply, and if this fails, cut off the air supply
3. Stall the engine by overloading

4-26. Whenever a diesel engine uses two filters in the fuel supply system, the primary or coarse filter will filter fuel between the

1. fuel pump and the carburetor
2. supply tank and the fuel supply pump
3. injection pump and the fuel nozzle
4. fuel supply pump and the injection pump

4-27. How does the fuel within a metal-disk filter flow?

1. The fuel enters the filter at the side inlet connection and, flowing in a circular motion, goes between the disks, and then goes out a side outlet connection
2. The fuel enters the filter at the top inlet connection and, flowing circular, goes around the disks, and then down a central passage to the outlet connection at the bottom
3. The fuel enters the filter at the top inlet connection and, flowing down, goes between the disks, and then up a central passage to the outlet connection at the top
4. The fuel enters the filter at an angle inlet connection and, flowing downward in a circle, goes between the disks, and then up a central passage to the outlet connection at the top

4-28. Water is removed from fuel oil by the metal disk filter because

1. of lack of clearance between the metal disks
2. water is absorbed in the dirt trapped between the disks
3. water in fuel oil forms globules which are trapped between the disks
4. water in fuel oil forms globules too large to pass the disks

4-29. The knife within the metal-disk filter is used for

1. slicing the large solids that may have fallen to the bottom of the filter housing so that they can be eliminated
2. cutting the large globules
3. scraping deposits off the filtering disks
4. cleaning the filter container when it is time to change the filter

4-30. Which of the following filters is designed with the greatest filtering quality?

1. Full-flow
2. Cloth-bag
3. Metal-disk
4. Fabric

4-31. Why is it necessary to have a supply pump to transfer fuel from the tank to the injection pump of a diesel engine?

1. Because the injection pump will not create sufficient suction
2. Because the fuel filters pass fuel only when under pressure
3. Because the injection pump will deliver excessive fuel to the engine
4. Because use of the injection pump alone will cause the fuel system to become airbound

4-32. In which of the following situations does the relief valve open in a fuel supply pump?

1. Fuel filters restrict the flow of fuel to the injection pump
2. Gears in the pump are worn
3. Springs in the pump are weak
4. One of the fuel lines develops a leak

In items 4-33 through 4-36, select from column B the function of the fuel injection system described in column A.

	A. Descriptions	B. Functions
4-33.	Force the fuel into the combustion chamber	1. Meter 2. Inject
4-34.	Break the fuel up into fine particles	3. Atomize
4-35.	Measure the amount of fuel to be injected	
4-36.	Distribute the fuel into the combustion chamber	

4-37. What type of injection system is used on Caterpillar diesel engines?

1. Unit injection
2. Pump and nozzle
3. Distributor
4. Pressure time

4-38. Which of the following repairs, if any, are to be made on a worn capsule-type nozzle?

1. Removal of an internal carbon accumulation
2. Replacement of the valve and seat
3. Renewal of the filter screen
4. None

4-39. Failure to tighten the capsule retainer properly on the capsule-type injection valve assembly may result in which of the following?

1. A damaged capsule
2. Poor injection
3. Fuel leaks
4. Each of the above

4-40. Fuel injection pumps may be interchanged between a 4- and 6-cylinder Caterpillar engine only if both engines have the same

1. horsepower rating and the entire pump assemblies are exchanged
2. horsepower rating and the original pump barrels are left in place
3. cylinder bore and the entire pump assemblies are exchanged
4. cylinder bore and the original pump barrels are left in place

4-41. What step should you take first when removing fuel injection pumps from the engine?

1. Clean the exterior of the pump housing
2. Remove the inspection plate on the housing
3. Disconnect the fuel injection lines
4. Remove the pump clamps

4-42. How are the injection pumps synchronized on the Caterpillar diesel engine?

1. By adjusting the lifters in the pump housing
2. By changing the effective length of the slide bar
3. By placing shims between the control rack and retaining plates
4. By alining marked teeth on the plunger gears and the rack

4-43. The slide bar of the governor transmits the movement of the governor weights directly to the

1. throttle
2. carburetor butterfly valve
3. injection pump control rack
4. plungers of the injection pumps

4-44. Assume that the high idle speed recommended by the engine manufacturer is 1,280 rpm. You should adjust the full-load speed of the engine to give an approximate tachometer reading of

1. 590 rpm
2. 640 rpm
3. 1,280 rpm
4. 2,360 rpm

4-45. Under which of the following engine operating conditions does the sleeve metering fuel pumps governor first assume control of fuel delivery?

1. Idle speed
2. Maximum speed, no load
3. Maximum speed, full load
4. Intermediate speed

4-46. In the mechanical flyweight governor, the action of the weights in their retainer is transmitted through a

1. sleeve to the governor arm and a linkage to the metering valve
2. governor arm to the sleeve and a linkage to the metering valve
3. sleeve to the governor arm and a metering valve to the linkage
4. governor arm to the sleeve and a metering valve to the linkage

In items 4-47 through 4-49, select from column B the component having the function in column A.

	A. Functions	B. Components
4-47.	Draws the fuel from the final filter into the pump through the inlet strainer	1. Metering valve 2. Cam lobe
4-48.	Determines the amount of fuel needed by the engine	3. Vane type fuel transfer pump
4-49.	Forces the plungers toward each other, discharging the fuel from the cylinder through the outlet port into the outlet passage in the hydraulic head and the fuel injection line connected to this passage	4. Delivery valve

4-50. The end plate of the Roosa Master fuel pump serves to do which of the following?

1. To provide passage for fuel and to cover and absorb end thrust of the transfer pump
2. To house the pressure regulator valve
3. To house the priming bypass spring which permits fuel to bypass the transfer pump during hand priming
4. All of the above

4-51. The plunger in an IH 817 series engine injector is actuated by means of

1. a spring
2. a cam
3. cylinder compression pressure
4. fuel injection pressure

4-52. The fuel entry port in an injector of an IH 817 series engine is uncovered during the

1. compression stroke only
2. intake stroke only
3. compression and intake strokes
4. power and exhaust strokes

4-53. Exhaust gases in an IH 817 series engine are prevented from flowing back into the injector fuel line by means of a/an

1. seated multi-orifice injector tip
2. injector check valve
3. injector plunger
4. injector fuel screen

4-54. By what means are the unit injectors actuated on the General Motors diesel?

1. Camshaft lobes
2. Push rods and rocker arms
3. Fuel pressure

4-55. Which of the following conditions must exist in a GM unit injector before it can inject fuel?

1. The lower port must be open and the upper port closed
2. The lower port must be closed and the upper port open
3. The lower and upper ports must be closed
4. The lower and upper ports must be open

4-56. Unit injectors are equalized by adjusting the

1. length of stroke of the injector plunger
2. diameter of the injection valve orifices
3. rack control levers
4. amount of centrifugal force exerted on the governor flyweights

4-57. During operation of the GM diesel, one cylinder has a lower temperature than the others. In order to supply this cylinder with more fuel, what adjustments should be made on its control rack?

1. Tighten the inner screw after loosening the outer screw
2. Tighten the outer screw after loosening the inner screw
3. Loosen the inner screw but maintain the setting of the outer screw
4. Loosen the outer screw but maintain the setting of the inner screw

4-58. Which of the following governors is NOT used on the GM series 71 engines?

1. Limiting speed mechanical
2. Spring control
3. Variable speed mechanical
4. Hydraulic

4-59. Engines requiring a minimum and maximum speed control, together with manually controlled intermediate speeds, are equipped with what type of governor?

1. Spring control
2. Limiting speed mechanical
3. Hydraulic
4. Variable speed mechanical

4-60. Engines subject to varying load conditions require what type of governor?

1. Hydraulic
2. Spring control
3. Variable speed mechanical
4. Limiting speed mechanical

4-61. What type of governor is used to maintain a constant engine speed with a minimum speed droop under varying load conditions?

1. Spring control
2. Hydraulic
3. Variable speed mechanical
4. Limiting speed mechanical

4-62. Which of the following is NOT a function of the variable speed mechanical governor for a "71" engine?

1. Controlling the amount of fuel for engine idle speed
2. Holding the amount of fuel flow constant under varying loads
3. Limiting the maximum no-load speed
4. Holding the engine at a constant speed between idle and maximum

4-63. Which of the following conditions may cause the engine speed to vary?

1. Faulty injector timing
2. Bind in governor parts
3. Change in load
4. Each of the above

4-64. The Cummins PT fuel system operates on which of the following principles?

1. An increase in fuel pressure will increase the rate of combustion
2. A decrease in fuel pressure will increase the rate of combustion
3. A change in fuel pressure will result in a corresponding change in fuel delivery rate

4-65. When operating at maximum governed speed, which component of the PT fuel pump limits the amount of fuel supplied to the injectors?

1. Governor plunger
2. Throttle shaft
3. Pressure regulator

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4-66. Assume that an engine idles at 550 rpm. What adjustment do you make while the engine is running to get it to idle at 500 rpm?

1. Turn adjusting screw on governor out to 500 rpm
2. Turn adjusting screw on governor out to 450 rpm
3. Turn adjusting screw on governor in to 500 rpm
4. Turn adjusting screw on governor in to 450 rpm

4-67. The purpose of the supercharger is to

1. force additional air into the engine cylinder
2. suck a higher charge of air in the cylinder
3. admit a higher charger of air by the receding piston
4. allow for an increase in horsepower by decreasing the speed

4-68. Which of the following is a basic part of a turbocharger?

1. Exhaust gas turbine
2. Impeller or compressor
3. Housing
4. Each of the above

4-69. When the turbocharger pumps a greater amount of air into the engine than would be applied by normal atmospheric pressure, there is a possibility that

1. more fuel will be burned and engine power will be decreased
2. less fuel will be burned and engine power will be decreased
3. more fuel will be burned and engine power will be increased
4. less fuel will be burned and engine power will be increased

4-70. The preheaters on some diesel engines assist in cold weather starting by heating the

1. fuel
2. inlet air
3. lube oil
4. coolant

4-71. Assume that a diesel engine has been operating normally and suddenly begins to puff thick, black smoke from its exhaust. The mechanic should first look for

1. an air lock in the fuel lines
2. a grease-clogged fuel injector
3. dirt or grit holding a spray nozzle open
4. water blocking an expansion loop in the fuel line

4-72. When a diesel engine is known to be in good mechanical condition but is hard to start and performs sluggishly, the trouble is most likely to be traced to

1. worn injector pumps
2. sticking rings
3. scored cylinder liners
4. sticking air intake valves

4-73. Which of the following can result when water enters the fuel system of a diesel engine?

1. Overspeeding
2. Missing and stalling
3. Smoking exhaust emissions
4. All of the above

4-74. When air is known to be in the fuel system of a diesel engine, which of the following procedures should you follow to remove the air?

1. Completely fill the fuel tank
2. Operate the engine at high idle for a short period of time
3. Bleed the fuel system
4. Idle the engine until its operating temperature is reached

4-75. In testing the injectors of a diesel engine that fails to operate properly, you cut out one cylinder at a time and observe engine operation. Which of the following conditions indicates a defective injector for the cut-out cylinder?

1. The defect is more pronounced
2. Irregular operation of the engine remains unchanged
3. Irregular operation of the engine is eliminated
4. Engine speed increases

Assignment 5

Cooling and Lubricating Systems

Textbook, NAVEDTRA 10644-G: Pages 122 - 147

Learning Objective: Indicate the relationship of the cooling system to efficient engine operation, point out design and functional features of individual cooling system components, and identify maintenance procedures applicable to cooling systems.

5-1. Cylinder wall temperature should not be allowed to exceed 500°F because

1. the combustion limit of the lubricating oil may be exceeded
2. no radiator coolants will withstand higher temperatures
3. excess exhaust gases build up faster than they can be expelled
4. lubricating oil films tend to break down with loss of lubricating properties

5-2. The approximate percentage of engine heat dissipated through the cooling, lubricating, and fuel systems is

1. 15%
2. 25%
3. 35%
4. 45%

5-3. In an air-cooled engine, cooling efficiency is dependent on which of the following factors?

1. Heat conductivity of the engine's metallic parts
2. Volume of air that circulates around engine surfaces
3. Difference between air temperature and engine temperature
4. Each of the above

5-4. Why are cylinders on an air-cooled engine mounted independently?

1. To reduce engine weight
2. To expose more surface area to the cooling medium
3. To eliminate the need for cooling system maintenance
4. To provide easy access to the crankcase

5-5. Which of the following components is required on all stationary air-cooled engines?

1. Baffles
2. Thermostats
3. Fans or blowers

5-6. Coolant in a liquid cooling system flows directly from the water pump to the

1. bottom of the radiator
2. cylinder block
3. cylinder head
4. top of the radiator

5-7. When the coolant in a multicylinder vehicular engine leaves the engine and passes through the radiator, heat is removed from the coolant by the

1. rapid evaporation of moisture from the radiator core surfaces
2. airflow through the radiator
3. circulation of the coolant through the water jacket
4. circulation of air around the engine block

5-8. A liquid cooling system's efficiency is affected by which of the following factors?

1. Size of the coolant passages in the engine
2. Capacity of the water pump
3. Size of the radiator
4. Each of the above

5-9. How do radiator fins contribute to cooling system efficiency?

1. They hold the tubes in a position that allows maximum contact with the air flow
2. They increase heat dissipation by enlarging the surface area exposed to air flow
3. They increase heat dissipation by enlarging the surface area exposed to the coolant
4. They direct the flow of air to the hottest parts of the radiator

5-10. A radiator is equipped with a 12-pound pressure cap. What effect does this cap have on the boiling point of the coolant?

1. Lowers it 36°
2. Raises it 36°
3. Lowers it 3°
4. Raises it 3°

5-11. One of the spring loaded valves in a pressure cap controls pressure in the cooling system whereas the purpose of the other is to

1. prevent the loss of coolant
2. seal the overflow pipe
3. control the flow of coolant in the radiator
4. prevent vacuum from building up in the radiator when it cools

5-12. You should be careful in removing the cap from a hot, pressurized radiator to avoid

1. rapid engine cooling
2. excessive coolant loss
3. being burned by the hot coolant

5-13. Which of the following types of water pumps are commonly used on liquid cooled engines?

1. Nonpositive displacement centrifugal
2. Positive displacement centrifugal
3. Positive displacement vane
4. Nonpositive displacement vane

5-14. Some liquid cooling systems use a shroud in conjunction with the fan to

1. reduce fan speed at high engine speeds
2. direct air from the fan to engine surfaces
3. increase the amount of air drawn by the fan through the radiator
4. improve the flow of air through the radiator at high engine speeds

5-15. Which of the following is a likely cause of noise, vibration, and frequent water pump failure?

1. An improperly adjusted drive belt
2. A bent fan blade
3. A strong solution of antifreeze

5-16. The purpose of a fan clutch used on some automotive engines is to

1. give the operator the option of disengaging the fan at high speed
2. increase the volume of air supplied to the fan
3. increase or decrease fan speed depending on engine temperature
4. disengage the fan when engine speed is increased

5-17. The water jacket of an engine consists of only those passages provided within the cylinder block for coolant circulation.

5-18. A coolant (water) distribution tube is used in the cooling systems of L-head engines in order to

1. disperse hot coolant that enters the top tank of the radiator
2. distribute the coolant equally between the cylinder block and cylinder head
3. direct the coolant to the cylinder head only
4. direct the coolant to the hottest parts of the cylinders

5-19. Why are thermostats used in automotive cooling systems?

1. To control engine operating temperatures
2. To prevent crankcase sludge buildup
3. To reduce fuel consumption
4. All of the above

5-20. During engine warmup, a thermostat restricts the coolant flow at the

1. radiator outlet
2. water pump inlet
3. cylinder head outlet
4. radiator inlet

5-21. What happens to a wide open thermostat when its bellows or pellet ruptures?

1. It closes completely
2. It remains wide open
3. It assumes a half-open, half-closed position

5-22. Shutters are placed in front of the radiators used with some engines to

1. block the flow of air through the radiator
2. prevent foreign matter from entering the radiator core
3. eliminate the need for a cooling fan
4. eliminate the need for a fan clutch

5-23. Radiator shutters used on large trucks are opened by

1. water temperature
2. vehicle speed
3. air temperature
4. air pressure

5-24. The expansion tanks in closed cooling systems serve to do which of the following?

1. Increase the system's cooling capacity
2. Eliminate the need for a pressure cap
3. Prevent coolant loss
4. Each of the above

5-25. What percentage of antifreeze is needed in a cooling system to provide maximum protection from freezing?

1. 40
2. 50
3. 60
4. 70

5-26. Efficient cooling system operation is most important under which engine operating condition?

1. Idle speed in slow traffic on hot days
2. Idle speed for long periods on cool days
3. High speeds on cold days
4. Intermediate speeds in fast moving traffic

5-27. What should you do to prevent unwanted aftereffects from the use of a cleaning compound in the cooling system of an engine?

1. Fill the system with a 60% solution of antifreeze
2. Reverse flush the cooling system
3. Follow up with the use of a neutralizing solution
4. Operate the engine at a high temperature for 10 minutes

5-28. In preparation for reverse flushing an engine block, you should do which of the following?

1. Remove the radiator cap
2. Disconnect the upper and lower radiator hoses from the engine
3. Disconnect the upper and lower radiator hoses from the radiator
4. Open the drain cock at the bottom of the radiator

5-29. When adding antifreeze to a cooling system, you do NOT need to do which of the following?

1. Determine the capacity of the cooling system
2. Thoroughly inspect the cooling system's components
3. Mix the antifreeze with water before adding to the cooling system

5-30. A coolant mixture containing 50% antifreeze will provide adequate protection against freezing to a maximum temperature of

1. 10°F
2. 0°F
3. -10°F
4. -30°F

5-31. After adding antifreeze to a cooling system, you should do which of the following?

1. Fill the radiator to operating capacity with water
2. Operate the engine to mix the solution
3. Check the solution with an antifreeze hydrometer
4. Each of the above

5-32. Which of the following problems could cause the coolant in a liquid cooling system to bubble or foam?

1. A leak in the lower radiator hose
2. A defective water pump seal
3. A leaking cylinder head gasket
4. Each of the above

5-33. To eliminate small air leaks at the lower radiator hose connections, you should do which of the following?

1. Replace the hose
2. Tighten the hose clamps
3. Coat the hose connections with gasket cement
4. Install an unvented radiator cap

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5-34. When preparing to check a cooling system to determine if exhaust gases are entering the coolant, you do NOT need to remove which of the following components?

1. Lower radiator hose
2. Upper radiator hose
3. Thermostat
4. Fan belt

5-35. In using the radiator pressure tester, how can you tell that a cooling system is leaking?

1. By a decrease in volume
2. By an increase in volume
3. By an increase in pressure
4. By a decrease in pressure

5-36. To find a compression leak in a V-8 engine with a radiator pressure tester, you should isolate the bank of cylinders containing the leak.

5-37. By testing the coolant in a cooling system with a hydrometer, you can determine whether or not the coolant will provide adequate protection against

1. leaking
2. clogging
3. freezing
4. boiling

5-38. Testing an antifreeze solution when its temperature is 50°F may result in a false reading because

1. antifreeze changes color when cooled
2. the solution is not thin enough
3. water and antifreeze are not soluble at this temperature
4. water tends to expand at this temperature

5-39. When back flushing fails to unclog the water jacket in an engine that is overheating, which of the following actions should you take?

1. Remove the cylinder head(s) and boil in a cleaning solution
2. Remove the core hole plugs and flush directly through the openings
3. Remove the old thermostat and replace it with one having a lower opening temperature
4. Replace the water pump or install a larger impeller

5-40. Radiator leaks are often caused by

1. vibration
2. rust
3. overheating

5-41. Why is a very small leak easier to detect in cooling systems that contain an antifreeze solution than in those that do not?

1. Antifreeze leaves a residue; water does not
2. More antifreeze leaks through than water
3. Antifreeze does not evaporate as fast as water
4. Antifreeze is colored; water is colorless

5-42. After shutting down an engine that has run for some time, you can check the radiator to see if it is partially clogged by

1. taking the temperature of the coolant in the lower radiator outlet
2. taking the temperature of the coolant in the upper radiator tank
3. feeling the top and bottom of the radiator core with your hand

5-43. After tightening the clamp on a new radiator hose, what should you do if the connection leaks?

1. Replace the hose
2. Replace the clamp
3. Put a sealer on the connection
4. Install a second clamp

5-44. A radiator hose that is suspected of being faulty but does not feel mushy must be removed for inspection if the hose is

1. preformed
2. molded
3. spring stiffened

5-45. Why do most water pumps require little or no maintenance?

1. They contain packing glands
2. They have sealed bearings
3. They are gear driven
4. Their impeller shafts are made of case hardened steel

5-46. A water pump fails to circulate an adequate volume of coolant. The problem is normally caused by

1. a loose fan belt
2. eroded impeller blades
3. worn pump housing
4. faulty shaft bearings

5-47. Correct fan belt tension is determined by measuring the

1. distance between the belt pulleys
2. width of the belt
3. deflection of the belt between pulleys

5-48. In most applications, you can remove the fan belt after loosening which of the following?

1. Air conditioner belt
2. Power steering belt
3. Fan blades
4. Generator mounting bolts

5-49. You are checking a cooling system and find a thermostat that fails to operate correctly. What should you do with the thermostat?

1. Repair it
2. Replace it
3. Clean it
4. Adjust it

5-50. A 180°F thermostat should be completely open when the coolant reaches 180°F.

Learning Objective: Identify types of lubrication systems and point out their operational characteristics and maintenance requirements.

5-51. The primary function of an engine's lubrication system is to

1. reduce friction
2. prevent overheating
3. eliminate engine seizure
4. provide a seal between the cylinders and rings

5-52. Which of the following is an operating principle of the 2-gear type of oil pump?

1. Both gears are independently driven by shafts
2. Both gears turn in the same direction
3. Pumping action forces oil to pass between the gear teeth
4. The pump is driven by the camshaft or distributor

5-53. Which of the following is an operating principle of the rotary oil pump?

1. The inner rotor is centrally located in the outer rotor
2. The pump is driven by the outer rotor
3. Its rotors turn in the same direction
4. Its rotors turn in opposite direction

5-54. Why is a relief valve placed in the lubrication system of an engine?

1. To prevent damaging the internal parts of the oil pump
2. To provide an adequate supply of oil to the suction side of the oil pump
3. To regulate pressure delivered by the oil pump
4. To prevent overlubrication of the engine bearings

5-55. The first indication of low engine oil pressure on some vehicles would be in the form of

1. high engine temperature
2. a warning light on the instrument panel
3. a knocking noise coming from the engine
4. a sudden loss of power

5-56. In an engine lubrication system, where will you find an oil strainer?

1. In the oil return line to the crankcase
2. At the inlet of the oil pump pickup tube
3. In the discharge line from the oil pump

5-57. Oil strainers sometimes contain a safety valve for the purpose of

1. limiting the amount of oil entering the oil pump
2. controlling the oil level in the oil pan
3. controlling pump discharge pressure
4. allowing oil to bypass a clogged screen

5-58. Dirt, water, and sludge do NOT pass through an oil strainer with the oil because of which of the following reasons?

1. All oil is collected from the surface of the oil in the oil pan
2. The mesh of the screen will allow only the lubricating oil to pass
3. The strainers are located above the bottom of the oil pan

5-59. Of the following, which is an advantage of using a full flow oil filter in a lubricating system?

1. The filter has the capacity to strain all the oil supplied by the oil pump
2. The filter never permits any unfiltered oil to reach the moving parts of the engine
3. The filter does not need changing as often as other types of filters
4. Each of the above

5-60. Why does the partial flow filter illustrated in textbook figure 5-16 contain a restriction?

1. To limit the amount of oil entering the filter
2. To allow adequate filtering of the oil that circulates through the system
3. To prevent unwanted contaminants from reaching the engine's moving parts
4. To insure adequate oil pressure in the lubricating system

5-61. The oil level gage for an engine indicates the exact amount of oil in the crankcase.

In items 5-62 through 5-64, select from column B the lubricating system described in column A.

	A. Descriptions	B. Lubricating Systems
5-62.	Valve mechanisms are lubricated by oil droplets and mist	1. Splash
		2. Combination splash and force-feed
5-63.	Oil under pressure lubricates the rod bearings; piston pins are splash lubricated	3. Force-feed
		4. Full force-feed
5-64.	Oil under pressure lubricates the rod bearings and piston pins	

5-65. Which of the following determines the frequency of engine oil changes for Navy vehicles?

1. Preventive maintenance schedules
2. Climatic conditions
3. Adverse operating conditions

5-66. In changing engine oil, when should you drain the oil from a vehicle?

1. When the engine is warm
2. Before the engine has been started
3. Anytime
4. Whenever the vehicle is deadlined

5-67. Which of the following types of oil filters must be disconnected from the oil lines before the filter can be dismounted?

1. Drain plug equipped partial flow type
2. Nonreplaceable element type
3. External bypass screw-on type
4. Nondrain equipped partial flow type

5-68. Assume that an EO reports that a vehicle has a low oil pressure reading. Which of the following conditions could be the cause?

1. Defective oil pump
2. Defective oil gage
3. Improper grade of oil or low oil level
4. Each of the above

5-69. Which of the following is indicated by a high oil pressure reading that recurs constantly?

1. Worn engine bearing
2. Overheated engine
3. Blocked oil passage
4. Diluted oil

5-70. Oil pump or pressure relief valve failure is normally the cause of low oil pressure.

5-71. Which of the following is the best method of determining how an oil pump is driven?

1. Remove the distributor to check whether or not it has a gear on the end of its shaft
2. Remove the oil pan to notice the way the pump is mounted
3. Consult the manufacturer's maintenance manual
4. Remove the oil pump to see whether it has a slot or a gear on the end of its shaft

5-72. Before installing a rotary oil pump, why should you fill the pump chamber with oil?

1. To prevent rotor damage when the engine is turned over
2. To eliminate air pockets that could restrict oil flow
3. To reduce the chances that the pump's shaft will bind
4. To make sure that the pump will work when the engine is cranked

5-73. The purpose of flushing an engine's lubricating system is to

1. keep the system clean
2. remove metal particles and sludge
3. remove particles that collect in the oil filter

5-74. When mixed with lubricating oil, which of the following solvents makes a good compound for flushing an engine?

1. No. 1 diesel fuel
2. No. 2 diesel fuel
3. Kerosene
4. Each of the above

5-75. While running an engine during the engine flushing process, what should you do on noticing a sudden increase in oil pressure?

1. Continue to run the engine; this increase is normal
2. Stop the engine, then restart after it cools off
3. Stop the engine and partially drain the crankcase before continuing
4. Shut off the engine, then check for clogged oil passages

Assignment 6

Automotive Electricity: Part I

Textbook, NAVEDTRA 10644-G: Pages 148 - 177

Learning Objective: Recognize fundamentals of automotive electricity.

In answering items 6-1 through 6-3, select from column B the term defined in column A.

A. Definitions	B. Terms
6-1. Flows in a single direction	1. Conductor
6-2. Flows from a source which changes polarity	2. Alternating current
6-3. Contains many free electrons	3. Insulator
	4. Direct current

In answering items 6-4 through 6-6, select from column B the term which is defined in column A.

A. Definitions	B. Terms
6-4. The amount of current flow	1. Voltage
6-5. The force that causes current flow	2. Conductor
6-6. The opposition to the flow of current	3. Amperage
	4. Resistance

6-7. The amount of current flow in a d-c circuit of fixed resistance is dependent upon

1. conductor size
2. circuit length
3. current direction
4. applied voltage

6-8. In an electrical circuit with a fixed resistance, a drop in voltage will cause a/an

1. increase in current flow
2. increase in circuit resistance
3. reduction in current flow
4. reduction in circuit resistance

6-9. Magnetic lines of force outside a magnet flow in paths from the

1. north pole to the south pole
2. south pole to the north pole
3. axis to the south pole
4. north pole to the axis

6-10. Which means of inducting current to flow in a conductor is applied to an automotive ignition coil?

1. Moving the conductor through a stationary magnetic field
2. Holding the conductor stationary while a magnetic field is moved through it
3. Holding stationary both the conductor and an electromagnet while current flow to the electromagnet is alternately started and stopped
4. Holding a charged rod near the conductor

6-11. In a lead-acid storage battery, current is produced by

1. magnetism
2. chemical reaction
3. ionization
4. thermal radiation

6-12. Why are the cell elements of a storage battery elevated inside the case?

1. To allow the electrolyte to circulate under the elements
2. To prevent the cells shorting against the bottom of the case
3. To reduce the amount of lead needed for connecting the cells and terminal posts
4. To prevent shorting of the cells when material from the plates settles to the bottom of the case

6-13. The capacity of a cell depends upon which of the following factors?

1. The area of the plates in contact with the electrolyte and the quantity and specific gravity of the electrolyte
2. The type of separators and the final limiting voltage
3. The general condition of the battery (degree of sulfating, plates buckled, separators warped, sediment in bottom of cells, and so forth)
4. All of the above

6-14. A 12-volt lead-acid, automotive battery consists of how many cells connected in series?

1. 12
2. 2
3. 6
4. 4

Learning Objective: Point out methods and techniques of servicing, testing, and maintaining storage batteries.

6-15. When taking a hydrometer reading of a battery whose temperature is 95°F, which of the following calculations do you perform to determine the actual specific gravity of the electrolyte?

1. Add 0.006 to your reading
2. Add 0.008 to your reading
3. Subtract 0.006 from your reading
4. Subtract 0.008 from your reading

6-16. In battery charging, either the current or voltage is kept constant.

6-17. What charging rate should you use in charging a 19-plate battery by the constant-current method?

1. 9 amp
2. 10 amp
3. 19 amp
4. 20 amp

6-18. What causes the value of the charging current to change in a constant voltage battery charger?

1. The battery increasingly resists current as its own charge builds up
2. A clock-actuated rheostat adjusts the current value
3. A rectifier tube automatically adjusts the current value
4. The operator changes plug-in positions to lower the charger's output at half-hour intervals

6-19. You are about to connect a battery to a charger when you notice that the terminal markings on the battery posts are completely obliterated. To insure correct battery-to-charger connections, you should

1. check the battery with an ammeter to determine the positive post
2. connect the larger battery post to the unmarked charger terminal
3. energize the charger and observe the charger gage reading as you touch the battery cables to the charger terminals
4. connect the larger battery post to the marked charger terminal

6-20. Of the following practices, which one should the mechanic observe when charging batteries?

1. Before charging, add sulfuric acid to any cell in which the electrolyte is below the plates
2. Before charging, remove vent plugs to prevent accumulation of gases
3. During charging, mark down frequent hydrometer readings to determine if the battery is functioning properly
4. Remove each battery for a 10-minute break when half charged

6-21. What should be done with a new 6-volt battery that only shows 4 volts on a voltmeter?

1. Add electrolyte
2. Recharge it
3. Discard it
4. Put it in service to see whether its voltage will increase or decrease

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6-22. After adding electrolyte to a charged-and-dry battery, you may have to charge the battery.

6-23. Which of the following is the safe way to mix electrolyte for a lead-acid battery?

1. Pour water into acid slowly and stir gently
2. Pour water into acid slowly and stir vigorously
3. Pour acid into water slowly and stir gently
4. Pour acid into water slowly and stir vigorously

6-24. Assume that you have been furnished with sulfuric acid of 1.400 specific gravity. Which of the following is the proper way to obtain an electrolyte of 1.290 specific gravity?

1. Pour 9 parts of water into 20 parts of the acid
2. Pour 8 parts of the acid into 3 parts of water
3. Pour 3 parts of the acid into 8 parts of water
4. Pour 20 parts of the acid into 9 parts of water

6-25. Which of the following instruments is recommended for determining whether or not a battery will function under a normal cranking load when it is installed in a vehicle?

1. Hydrometer
2. Voltmeter
3. Light load tester
4. Battery starter tester

Learning Objective: Point out the purpose and operating principles of automotive generators.

6-26. The generator converts mechanical energy into electrical energy and restores the battery with the energy it expends.

6-27. The current generated by an alternator is converted to direct current by means of a/an

1. armature coil
2. condenser
3. rectifier
4. stationary field coil

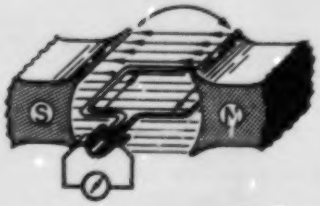

Figure 6A.

6-28. Why is the emf induced in the armature coil of a d-c generator at its maximum value when the armature coil is in the position shown in figure 6A?

1. Because the density of the lines of force is greatest
2. Because the armature coil is cutting the greatest number of lines of force per second
3. Because the armature coil is moving almost parallel with the field
4. Because the brushes are in most effective contact with the commutator segments

6-29. The alternating current in the armature coil of a d-c generator is changed to direct current in the external circuit by the

1. armature
2. commutator
3. changes in the polarity of the field
4. slip rings

6-30. What is the purpose of the field windings in a d-c generator?

1. To increase the strength of the magnetic field
2. To decrease the strength of the magnetic field
3. To permit a smoother flow of current
4. To change alternating current to direct current

6-31. The output of a d-c generator is determined by which of the following factors?

1. Speed of the armature rotation
2. Number of armature conductors
3. Strength of the magnetic field
4. All of the above

6-32. The current regulator functions to protect the electrical system by

1. limiting the battery output
2. limiting the generator output
3. disconnecting electrical accessories
4. warning the equipment operator

6-33. The vibrating-type voltage regulator functions to protect the electrical system from possible damage due to high circuit voltages by

1. adding and removing resistance in the generator field
2. short circuiting the generator armature windings
3. increasing the system's electrical load
4. disconnecting the battery from the system

6-34. The magnetic field in an alternator is created by which of the following?

1. Residual magnetism contained in the rotor pole pieces
2. Residual magnetism contained in the stator assembly
3. current passing through the rotor coil to ground

6-35. How are the stator windings connected in an alternator?

1. One end of each winding is connected to a positive diode and the other to a negative diode
2. One end of each winding is connected to both a negative and a positive diode, while the other ends are interconnected internally in the stator
3. One end of each winding is connected to a negative diode and the other end to a pair of positive diodes

6-36. How many diodes are grounded in an alternator assembly?

1. 1
2. 6
3. 3
4. 4

Learning Objective: Describe the fundamentals of maintaining and testing generators.

6-37. What causes solder globules to form inside the cover band of a generator?

1. Excessive current output
2. An open field circuit
3. Excessively worn brushes
4. Internally shorted armature

6-38. Weak brush springs in a d-c generator will result in arcing and burning of the commutator and brushes.

6-39. Which of the following is a poor practice in the disassembly of a generator?

1. Before removing the end frames, place the generator on end
2. Check for marks which will help you line up the parts correctly when you reassemble the generator
3. Before removing the brush end, disconnect the leads of the field coil
4. After removing the brushes from their holders, ease up the brush spring tension

6-40. A test lamp lights with normal brilliance when it is connected to the field lead terminal of a generator. What does this indicate?

1. An open field
2. A normal field
3. A shorted field
4. A grounded field

6-41. A test lamp lights when it is connected to the frame and one field terminal of a generator. What does this indicate?

1. An open field
2. A normal field
3. A shorted field
4. A grounded field

6-42. Which of the following resistance readings is most likely if an ohmmeter is placed across a shorted field coil?

1. 1 ohm
2. 100 ohms
3. 100,000 ohms
4. 10 megohms

6-43. What type of flux is used for soldering electrical connections?

1. Borax
2. Acid
3. Rosin
4. Sal ammoniac

6-44. Of the following armature test/inspection findings, which indicates the need to turn down the commutator?

1. Run-out is 0.001
2. Segments are discolored
3. Segments are 3/32 in. thick
4. Insulation extends above the segments

6-45. Assume that after you have turned an out-of-round commutator, you measure the commutator and find each of its segments to be 3/4 inch thick. What should you do next?

1. Turn the commutator until the segments are thinner
2. Install the armature back in its frame
3. Replace the armature
4. Undercut the mica between the commutator bars

6-46. Assume that a thin steel strip is held over the core of an armature that is placed in a growler and rotated with the current on. If the strip begins to vibrate, the circuit in the armature is probably

1. open
2. shorted
3. normal
4. grounded

6-47. If a milliammeter reading near zero is obtained across a pair of commutator segments on an armature that is mounted in a growler, the coil is

1. open
2. shorted
3. normal
4. grounded

6-48. What should be done if tests of an armature indicate an open coil winding after the connections to the commutator bars are resoldered?

1. Replace the commutator bars
2. Replace the individual coil
3. Replace the entire coil assembly
4. Discard the armature

6-49. What device is used to measure the tension of brush springs?

1. Hook scale
2. Torque wrench
3. Ohmmeter
4. Feeler gage

6-50. Which of the following methods should be used to polarize the field of a generator in an externally grounded system?

1. Momentarily connect the regulator field terminal to the regulator battery terminal with a jumper wire
2. Connect the regulator field terminal to ground for a moment
3. Connect the regulator battery terminal to ground for a moment
4. Connect the regulator generator terminal to the regulator battery terminal momentarily, using a jumper wire

6-51. Which of the following methods should be used to polarize the field of a generator in an internally grounded system which has a single contact voltage regulator?

1. Momentarily connect a jumper between the field terminal and the battery terminal of the regulator
2. Momentarily touch the battery terminal of the regulator with the lead from the field terminal of the regulator
3. Momentarily connect the regulator armature terminal to the regulator battery terminal
4. Momentarily touch the regulator battery to a ground

6-52. Grounding the field terminal of an alternator will result in damage to the

1. regulator
2. diodes
3. rotor windings
4. battery

6-53. A charging system containing an alternator can be checked for proper operation by means of a/an

1. screwdriver
2. ammeter
3. voltmeter
4. jumper wire

6-54. To determine if an alternator rotor is internally shorted, you test the rotor windings with which device?

1. Armature growler
2. Test lamp
3. Galvanometer
4. Ohmmeter

6-55. Testing of an alternator stator is limited to

1. shorts and opens
2. opens and grounds
3. grounds and shorts

Assignment 7

Automotive Electricity: Part II

Textbook, NAVEDTRA 10644-G: Pages 178 - 216

Learning Objective: Indicate the purpose of the components, the principles of operation, and maintenance procedures for cranking systems.

7-1. In a modern starting circuit, which component provides battery current directly to the starter?

1. Ignition switch
2. Solenoid
3. Pushbutton switch

7-2. What causes the starter pinion on an inboard drive starter to engage the flywheel?

1. A lever attached to the solenoid
2. Magnetic repulsion
3. Spring pressure
4. Centrifugal force

7-3. In a starting motor, which of the following features permits a large current flow for developing high torque?

1. Low resistance in the field and armature windings
2. Current fed to both the field and armature windings
3. The strong magnetic field surrounding the field coils
4. The large number of windings contained in the field and armature coils

7-4. The mechanism which causes the drive pinion to mesh with the flywheel by inertia is known as the

1. Bendix drive
2. overrunning clutch
3. Dyer drive
4. reduction drive

7-5. Starter motors equipped with a Bendix drive will not start to turn until the starter is engaged with the flywheel.

7-6. On starter motors equipped with an overrunning clutch drive mechanism, how is the starter pinion disengaged when the engine starts?

1. Automatically by centrifugal force
2. Automatically by inertia
3. By action of the springs and rollers
4. By movement of the collar and spring assembly

7-7. In a starting circuit containing a solenoid, when is battery current supplied to the starter motor?

1. When the remote control switch is closed
2. At the time the ignition is turned to the start position
3. After the starter pinion is engaged with the flywheel
4. When the plunger closes the contacts in the solenoid

7-8. Continued starter operation after releasing the starter button or ignition key is often caused by

1. a broken Bendix spring
2. a worn solenoid plunger
3. shorted solenoid windings
4. a faulty pinion and rotor assembly

7-9. Which of the following starting circuit components is common to all vehicles and equipment having automatic transmissions?

1. Starter solenoid
2. Relay
3. Neutral safety switch
4. Double reduction starter

7-10. Two 12-volt batteries connected in parallel will supply 24 volts for cranking a high compression engine.

● When answering items 7-11 through 7-13, refer to textbook figures 7-7 and 7-8.

7-11. How many volts are delivered to the starting motor when the starting switch is engaged?

1. 0
2. 6
3. 12
4. 24

7-12. Generator charging current flows from battery B to ground through the

1. cranking motor
2. series-parallel switch
3. solenoid
4. generator

7-13. Which of the following voltages is delivered to the accessories while the engine is being cranked?

1. 6 v from battery A
2. 12 v from both batteries
3. 12 v from battery A
4. 24 v from both batteries

7-14. Normally, a starter that is operated for excessive periods of time will fail because of

1. burnt brushes
2. shorted solenoid windings
3. loose commutator segments
4. insulation failure

7-15. If a vehicle's starter fails to function, the first component you should check for possible trouble is the

1. starter switch
2. starter motor
3. remote-control relay
4. battery

7-16. To perform an accurate battery capacity test, which of the following items of information must you have?

1. The ampere-hour capacity of the battery
2. The number of positive plates per cell
3. The number of negative plates in the battery
4. The specific gravity of the electrolyte

7-17. Before reassembling a starting motor, which of the following steps should you take?

1. Replace the brushes
2. Clean the armature with diesel
3. Coat the drive mechanism with chassis lube
4. Test the brush spring tension

7-18. Which of the following procedures is recommended for freeing a starter that is locked to the engine flywheel?

1. Cranking the engine with a hand crank
2. Shifting into a forward gear and pushing the vehicle backward
3. Loosening the starter fastening bolts
4. Each of the above

Learning Objective: Indicate the purpose and function of ignition system components and point out procedures for maintaining and testing these components.

7-19. Of the three types of ignition systems, which requires the LEAST maintenance?

1. Battery
2. Magneto
3. Transistorized

7-20. A battery-ignition system consists of how many circuits?

1. One
2. Two
3. Three
4. Four

7-21. Operating an engine with no primary circuit resistance will result in

1. rapid point failure
2. excessive secondary voltage
3. frequent spark plug failure
4. shorting of the distributor capacitor

7-22. Which component of a battery-ignition system provides high voltage in the secondary circuit?

1. Distributor
2. Ballast resistor
3. Capacitor
4. Coil

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7-23. The distributor contact points and cam provide a means of opening and closing the primary circuit.

7-24. One of the functions of the condenser in a battery-ignition system is to

1. stop the flow of magnetic lines of flux when the points open
2. act as a safety gap for the secondary coil
3. allow a rapid collapse of the magnetic field around the primary winding
4. regulate the flow of current through the secondary winding

7-25. Which of the following is the purpose of the distributor in the ignition system?

1. To open and close the primary circuit, to produce the magnetic buildup and collapse, in the ignition coil
2. To conduct the high voltage surges from the secondary winding at the proper time
3. To direct high voltage surges to the proper spark plugs
4. All of the above

7-26. In a battery-igntion system, high voltage is directed to the spark plugs in the correct firing order by the

1. battery
2. ignition coil
3. timer coil
4. rotor

7-27. How many types of advance mechanisms are used on a conventional battery-ignition system?

1. One
2. Two
3. Three
4. Four

7-28. In a modern distributor, which of the components is made to rotate by the advance mechanism?

1. Rotor
2. Cam
3. Breaker plate
4. Distributor housing

7-29. At what approximate speed will the mechanical advance mechanism in a distributor normally start to function?

1. 700 rpm
2. 1000 rpm
3. 1200 rpm
4. 1500 rpm

7-30. The vacuum type of spark advance mechanism is connected between the

1. carburetor and spark plugs only
2. spark plugs and distributor only
3. distributor and carburetor only
4. distributor, spark plugs, and carburetor

7-31. Which component of the battery-ignition system was eliminated by early model transistorized ignition circuits?

1. Points
2. Condenser
3. Coil
4. Rotor

7-32. A rotating piece is used in the distributor of a transistorized ignition circuit for the purpose of

1. disturbing the magnetic field so that a current pulse is induced in the pickup coil
2. directing the high secondary voltage to the correct spark plug terminal of the distributor
3. absorbing the voltage surge in the primary circuit
4. advancing ignition timing under various load and speed conditions

7-33. Why do transistorized ignition circuits operate with higher secondary voltages than older conventional ignition systems?

1. To ignite the leaner fuel mixtures used in modern engines
2. To overcome high resistance in the secondary wiring
3. To offset any changes that may occur in the coil saturation period

7-34. Which component of the battery-ignition system is eliminated by the use of a magneto?

1. Rotor
2. Contacts
3. Coil
4. Battery

7-35. Which component of a magneto enables it to produce initial starting current during cranking?

1. Horseshoe magnet
2. Oversized coil winding
3. Impulse coupling

7-36. When troubleshooting the secondary circuit of a transistorized ignition, which of the following procedures should you use?

1. Hold a spark plug wire approximately 1/2 inch from a good ground
2. Use an insulated tool to hold a plug wire approximately 1/4 inch from a good ground
3. Ground the coil with a screwdriver to see if it will produce a spark
4. Remove a spark plug and hold the tip approximately 1/4 inch from the block

7-37. Which of the following will shorten the useful life of a spark plug?

1. Improper ignition timing
2. Reduced contact gap setting
3. Incorrect carburetor adjustment
4. Low battery voltage

In items 7-38 through 7-41, select from column B the condition that causes the kind of deposit in column A to form on the firing ends of spark plugs.

	A. Kinds of Deposit		B. Conditions
7-38.	Grayish-tan	1.	Rich fuel-air mixture
7-39.	Dry, fluffy black	2.	Correct spark plug heat
7-40.	Wet and oily		
7-41.	Yellow powdery	3.	Worn piston rings

7-42. Which of the following conditions indicates that a spark plug was not installed tight enough?

1. Blistered insulator tip
2. Cracked insulator
3. Powdery deposit on the plug
4. All of the above

7-43. When an engine is converted to burn liquefied petroleum, the spark plugs should be replaced with ones of a colder heat range to reduce

1. carbon deposits
2. pre-ignition
3. electrode wear

7-44. When cleaning spark plugs by the sand-blasting method, which of the following procedures should you follow?

1. Use long blasts while rocking the plug
2. Use short blasts while holding the plug still
3. Use long blasts while holding the plug still
4. Use short blasts while rocking the plug

7-45. How often should spark plugs be regapped?

1. Each time a vehicle is serviced
2. At 6000-mile intervals only
3. When they are removed for cleaning only
4. Any time they are removed for inspection

7-46. When distributor points become burnt or pitted, what should you do?

1. Clean the points with a special file
2. Remove any burrs or pits with fine grit sandpaper
3. Discard them and install a new set

7-47. A fluctuation in ignition timing can be caused by a

1. worn distributor bushing
2. faulty condenser
3. rich fuel mixture
4. restricted exhaust system

7-48. After installing contact points, you find the faces do not make full contact. Which of the following steps should you take?

1. File the faces straight across the edge that is riding high
2. Bend the movable breaker arm
3. Bend the stationary contact bracket

7-49. To obtain an accurate reading on the dwell meter when checking the cam angle of a distributor, you should start by adjusting the

1. contact points gap
2. breaker plate position
3. tension of the contact point spring
4. breaker arm alinement

7-50. When timing a vehicle's engine and the timing mark does not line up with the reference pointer, what should you do?

1. Turn the idling screw counterclockwise
2. Move the timing light lead to another plug
3. Rotate the distributor
4. Turn the idling screw clockwise

7-51. Which of the following kinds of test equipment can be used to diagnose a faulty distributor vacuum unit?

1. Vacuum gage
2. Timing light
3. Dwell meter

Learning Objective: Identify principles of lighting circuit operation and techniques for maintaining wiring circuits.

7-52. The purpose of the indicating or position lights on a heavy-duty truck is to indicate

1. whether the load within the truck is balanced
2. which direction the driver is about to turn the truck
3. the length, height, and width of the vehicle
4. whether all components of the lighting system are functioning properly

7-53. In an automotive lighting system fitted with fuses instead of curcuit breakers, there are as many fuses as there are

1. bulbs
2. switches
3. lights
4. ground wires

7-54. Navy automotive and construction equipment lighting systems operate on which of the following voltages?

1. 2 or 6 volts
2. 6 or 12 volts
3. 12 or 24 volts
4. 18 or 24 volts

7-55. Which of the following do you determine by measuring the intensity of a vehicle headlamp?

1. How far in front of the vehicle the headlamp focuses on the pavement
2. The amount of diffusion provided by a lens in the lamp
3. The amount of light produced by the lamp

7-56. When a vehicle's headlamps are centered 28 inches from the ground, how high should the reference line on the aiming screen be above ground level?

1. 24 in.
2. 26 in.
3. 28 in.
4. 30 in.

7-57. How far in front of a vehicle should you locate the aiming screen when alining headlamps?

1. 10 ft
2. 15 ft
3. 20 ft
4. 25 ft

7-58. When headlamps are correctly aimed, how far will the high intensity light beams drop for every 25 feet of distance from the bulb?

1. 1 in.
2. 2 in.
3. 3 in.
4. 4 in.

7-59. The aiming of a truck's headlamps differs from the aiming of an automobile's headlamps to compensate for the

1. greater height of the truck
2. smaller width of the automobile
3. effect of the heavier loads the truck carries
4. larger truck headlamps

7-60. Which of the following can cause a headlamp to show a poor candlepower reading?

1. A faulty ground
2. Loose connections
3. Undersized wiring
4. Each of the above

7-61. To eliminate the possibility of a short when changing switches and other electrical system components, what should you do?

1. Tag the wires
2. Change the wires one at a time
3. Remove the fuses
4. Disconnect the battery

7-62. On vehicles having a dual braking system, where is the brake light switch located?

1. In the hydraulic line between the master cylinder and wheel cylinders
2. Directly above the master cylinder
3. On the brake pedal support bracket

7-63. In the maintenance and repair of electrical systems, the most difficult task is

1. determining system polarity
2. troubleshooting
3. hooking up test equipment
4. tracing wiring diagrams

7-64. In some electrical systems, two-wire circuits are highly reliable for which of the following reasons?

1. They provide a positive path to and from the power source
2. They provide a dual path for current to flow from the power source
3. They eliminate the need for fuses or circuit breakers
4. They allow current to flow should one wire break

7-65. Where should you start tracing a circuit to locate a suspected wiring problem?

1. At the power source
2. At the inoperative component
3. Anywhere in the circuit

7-66. On which of the following kinds of equipment will you find numbered tags that identify the wiring circuits?

1. Sedans
2. M-series vehicles
3. Crawler-mounted equipment
4. Wheel-mounted construction equipment

7-67. Electrical symbols are used in wiring diagrams for which of the following purposes?

1. To simulate the electrical components
2. To identify the wires
3. To show the routing of the wires
4. To pinpoint the location of the components

7-68. Of the following electrical faults, which can cause an open circuit?

1. Corroded terminal
2. Loose connection
3. Broken wiring
4. Each of the above

7-69. Wires passing through holes in metal members of the body or frame should be protected

1. plastic clamps
2. flexible tubing
3. rubber grommets
4. electrical tape

7-70. In soldering, which of the following surface conditions will keep you from making a good soldered connection?

1. Dirty surface
2. Greasy surface
3. Oxidized surface
4. Each of the above

7-71. Which of the following is an advantage of using the induction-type soldering gun for electrical repair work?

1. Its small tip fits in confined spaces
2. Its tip heats rapidly
3. It focuses light on the work
4. Each of the above

7-72. Assume that you had to solder a connection within an area that could not withstand very much heat. Which of the following grades of solder should you use?

1. 30-70
2. 40-60
3. 50-50
4. 60-40

7-73. When used to repair electrical wiring, a solderless connector makes it impossible to obtain a

1. tight connection
2. cold solder joint
3. strong connection

7-74. When used to make electrical repairs, which of the following types of tape provides the best insulation?

1. Rubber
2. Plastic
3. Friction

7-75. Which of the following electrical problems will affect the operation of both the turn signals and the emergency flashing lights?

1. Faulty turn signal flasher
2. Inoperative directional control switch
3. Burnt-out turn signal bulb
4. Shorted tail light wiring

Assignment 8

Automotive Power Trains

Textbook, NAVEDTRA 10644-G: Pages 217 - 256

Learning Objective: Identify operating principles and maintenance practices of vehicular components that transmit power.

8-1. What transmits the power developed by the engine to the wheels and/or tracks and accessory equipment on a vehicle?

1. Crankshaft
2. Power train
3. Intake manifold
4. All of the above

8-2. Which of the following power train groups are arranged in the order through which power flows from the engine to the wheels of a light truck?

1. Transmission, clutch, propeller shaft, differential, and axles
2. Clutch, propeller shaft, transmission, differential, and axles
3. Clutch, transmission, differential, propeller shaft, and axles
4. Clutch, transmission, propeller shaft, differential, and driving axles

8-3. Which device is used to disconnect the engine from the power train?

1. Universal joint
2. Transfer case
3. Clutch
4. Differential

8-4. Which of the following statements describes one of the functions of the clutch in the power train of a motor vehicle?

1. It dampens vibration in the transmission system
2. It allows the brakes to "clutch," or hold while the vehicle is in motion
3. It transmits power to the wheels through the dead axles
4. It allows the engine to take up the vehicle-drive load gradually

8-5. When the clutch pedal is depressed, the pressure plate is retracted by

1. spring pressure
2. release levers
3. centrifugal force
4. splines on the clutch shaft

8-6. When the clutch disk is disengaged, where does it position itself?

1. Against the flywheel
2. Against the pressure plate
3. Centrally between the flywheel and pressure plate

8-7. Which of the following can cause rapid failure of the clutch release bearing?

1. Driving with your foot resting on the clutch pedal
2. Improper adjustment of the clutch
3. A broken or weak clutch pedal return spring
4. Each of the above

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8-8. How is a hydraulically operated clutch adjusted?

1. By turning the eccentric bolt in the clutch pedal support
2. By shortening or lengthening the slave cylinder push rod
3. By lengthening the effective stroke of the master cylinder's piston
4. By bleeding off a small amount of fluid at the slave cylinder

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In items 8-9 through 8-16, select from column B the clutch trouble which generally develops as a result of the condition in column A.

	A. Conditions		B. Clutch Troubles
8-9.	Loose spring shackles	1.	Slipping
8-10.	Broken parts in the clutch	2.	Dragging when disengaging
8-11.	Excessive free pedal adjustment	3.	Chattering or grabbing when engaging
8-12.	Bent crankshaft flange	4.	Pulsating pedal
8-13.	Loose transmission mountings		
8-14.	Worn engine mounts		
8-15.	Worn clutch facings		
8-16.	Uneven release-lever adjustment		

8-17. When an EO reports that the vehicle has a clutch-pedal pulsation, what does this mean to you as a CM?

1. A series of slight movements can be felt on the clutch pedal or operating lever when the clutch is being disengaged
2. There is slippage between the clutch disk facings and the flywheel or pressure plate
3. There must be dirt or grease on the clutch facings because there is a grinding noise when the clutch is disengaged
4. The clutch has a terrific jerk when it is engaged

8-18. Clutch-pedal pulsation may be caused by which of the following conditions?

1. Misalinement of the engine and transmission
2. The flywheel not being seated on the crankshaft flange
3. A warped pressure plate or warped clutch disk
4. Each of the above

8-19. A pilot bearing that is worn or lacks lubricant will produce noise in the clutch when which of the following conditions exists?

1. The transmission is in gear
2. The clutch is disengaged
3. The vehicle is standing still
4. All of the above

8-20. Which of the following conditions causes rapid clutch disk wear?

1. Incorrect adjustment
2. Improper use
3. Weak pressure springs
4. Each of the above

8-21. When disassembling a clutch, which of the following actions should you take before removing the pressure plate?

1. Mark the cover and flywheel
2. Relieve the tension on the pressure springs
3. Check the thickness of the clutch disk
4. Loosen the flywheel mounting bolts

8-22. When overhauling a clutch, you should inspect the pressure plate and flywheel for which of the following defects?

1. Cracks
2. Score and grooves
3. Warpage
4. All of the above

8-23. Which of the following is seldom done when clutches are overhauled in the maintenance shop?

1. Relining clutch disks
2. Replacing pilot bearings
3. Adjusting pressure plates
4. Replacing release bearings

8-24. What is the maximum number of adjustments that you may find on a pressure plate assembly?

1. One
2. Two
3. Three
4. Four

8-25. What should you do with a clutch release bearing that runs roughly?

1. Clean the bearing with solvent
2. Clean the bearing with degreasing compound
3. Clean the bearing with oil
4. Replace the bearing

8-26. Which of the following components transfers engine power from the clutch shaft to the propeller shaft?

1. Clutch
2. Axle
3. Transmission
4. Differential and universal joint

8-27. The constant mesh transmission reduces noise by utilizing

1. spur-tooth rather than helical gears
2. helical rather than spur-tooth gears
3. main shaft meshing gears that are able to move endwise
4. soundproof padding around the transmission units

8-28. The function of the friction cone clutch in a synchromesh transmission is to

1. engage the main drive gear with the transmission main shaft
2. engage the first speed main shaft with the transmission main shaft
3. equalize the speed of the driving and driven members
4. engage the second speed main shaft with the transmission main shaft

8-29. The purpose of the shift fork within the synchromesh transmission is to

1. lock the main drive gear and transmission main shaft
2. synchronize the speed of mating parts before they engage
3. move the sliding gear and sliding sleeve as a unit
4. slide over the balls within the clutch and silently engage the external teeth on the main drive gear

In items 8-30 through 8-33, select from column B the gear position of the auxiliary transmission that best fits the action as described in column A.

	A. Description	B. Gear Positions
8-30.	The dog clutch makes a direct connection between the input shaft and the main shaft	1. Direct speed 2. Low speed 3. Neutral
8-31.	Power is transmitted straight through the auxiliary transmission to the propeller shaft	
8-32.	The dog clutch is disengaged from the main-drive gear	
8-33.	Causes the engine to drive the wheels very slowly	

8-34. Which of the following conditions may cause noise that is difficult to diagnose and may seem to originate in the transmission?

1. Worn universal joints
2. Loose drive shaft center bearings
3. Worn ring and pinion gear
4. Each of the above

8-35. If flushing is required, the interior of the transmission case should be flushed with

1. a special oil
2. transmission lubricant
3. solvent
4. detergent

8-36. When determining whether or not to use an old transmission part, which of the following factors should you consider?

1. Serviceability of the old part
2. Cost of replacing the part
3. Availability of a new part
4. All of the above

8-37. How should you prepare leather oil seals before you install them in a transmission?

1. Give them a light coat of light oil
2. Give them a light coat of medium grade preservative lubricating oil
3. Soak them in light oil
4. Soak them in medium grade preservative lubricating oil

8-38. Transmission parts that are ready for reassembly should be coated with

1. light lubricating oil
2. medium grade preservative lubricating oil
3. rust-preventive compound
4. fiber grease

8-39. What device provides the means for automatically implementing a front wheel drive on an automotive vehicle?

1. Sprag unit
2. Power takeoff
3. Auxiliary transmission
4. Two-way clutch

8-40. In the transfer case, worn or broken gears, worn bearings, and excessive end play in the propeller shaft will cause

1. clashing gears
2. hard shifting
3. an unbalanced propeller shaft
4. noisy operation

8-41. In an automotive vehicle, the power takeoff that supplies power to the auxiliary accessories can be attached to which of the following units of the power train?

1. Transmission
2. Auxiliary transmission
3. Transfer case
4. Each of the above

8-42. Within the power takeoff attachment, the shifter shaft is held in position by a

1. shift lock
2. fork
3. spring-loaded ball
4. sliding spur gear

8-43. Some vehicle power takeoff units have two speeds forward and one in reverse, whereas some have several forward speeds and a reverse gear. The power takeoff units with the several forward speeds are used to operate

1. power trains
2. winches
3. tracklayers
4. front wheel drives

8-44. Failure of a power takeoff to operate is usually the result of

1. bent or broken linkage
2. faulty bearings
3. broken gear teeth
4. leaking shaft seals

8-45. Which of the following drive line components is used only on long wheelbase vehicles?

1. Universal joint
2. Slip joint
3. Support bearing
4. Propeller shaft

8-46. When torque rods are used with the Hotchkiss drive, their function is to

1. prevent spinning of the wheels on slippery surfaces
2. assist the springs in supporting the vehicle weight
3. maintain proper alinement of the axle and frame
4. eliminate the need for wheel balancing

8-47. Which component of a drive train is used to allow changes in the angle of the propeller shaft?

1. Support bearing
2. Companion flange
3. Slip joint
4. Universal joint

8-48. Which of the following propeller shafts is designed to prevent shaft speed fluctuations?

1. A shaft containing two universal joints assembled 90° apart
2. A shaft containing one universal joint and a slip joint on the same end of the shaft
3. A shaft containing one universal joint at the transmission end and a slip joint at the differential end
4. A shaft containing one universal joint at the differential end and a slip joint at the transmission end

8-49. When reassembling a universal joint, which of the following should you use to prevent the needles from falling out of the bearing?

1. Vaseline
2. Chassis grease
3. Water pump lubricant
4. Wheel bearing grease

8-50. Lubricating universal joints with a low pressure grease gun will prevent

1. bearing damage
2. seal damage
3. bearing seizure
4. overlubrication

8-51. Which of the following conditions indicates that a center support bearing is faulty?

1. A squealing noise in the drive train
2. Failure of the vehicle to start moving smoothly
3. Frequent stalling when the clutch is engaged
4. Vibration from the chassis at low speed

8-52. When replacing a center support bearing assembly, you should insure that

1. the bearing shield contains waterproof grease
2. a grease fitting is present
3. drive shaft alinement is maintained

8-53. The purpose of pillow block bearings in an auxiliary power train is to accomplish which of the following?

1. Support the drive shaft
2. Maintain shaft alinement
3. Prevent whipping at high speed
4. All of the above

8-54. Why are automotive driving axle assemblies vented?

1. To cool the lubricant
2. To eliminate internal pressure
3. To prevent overfilling

8-55. The function of the final drive in an automotive vehicle is to

1. change the direction of drive while providing a fixed reduction
2. allow the axles to turn at different speeds when cornering
3. prevent the driving wheels from losing traction
4. transmit power directly to the driving axles

8-56. Which of the following is indicated by the first number of a final drive ratio?

1. The number of times the ring gear turns in relation to the axle shafts
2. The number of times the axle shafts turn in relation to the drive shaft
3. The number of times the pinion shaft turns in relation to the drive shaft
4. The number of times the drive shaft turns in relation to the axle shafts

8-57. Which of the following units can be considered as a part of the final drive?

1. Slip joint
2. Shaft yoke
3. Flange yoke
4. Hypoid gear

8-58. Which type of final drive is used in 5-ton military designed vehicles?

1. Single-reduction
2. Double-reduction
3. Two-speed
4. A combination of 2 and 3 above

8-59. A two-speed final drive is limited to use in those vehicles which contain

1. one driving axle
2. two rear driving axles
3. both front and rear driving axles

8-60. The purpose of the differential in the rear axle assembly is to

1. connect the rear axle shafts
2. permit the axles to turn at different speeds
3. boost engine power transmitted to the wheels
4. permit both drive axles to be driven as a single unit

8-61. Which parts of the differential transmit power directly to the axle shafts?

1. Differential case and side gears
2. Bevel drive pinions and side gears
3. Differential pinions and side gears
4. Differential case and bevel drive pinions

8-62. Which of the following components supports part of the weight of a vehicle and also drives the wheels connected to it?

1. Axle trunnion
2. Live axle
3. Dead axle
4. Bogie drive

8-63. Which of the following components carries part of the weight of a vehicle, but does not drive the wheels?

1. Chassis
2. Axle trunnion
3. Live axle
4. Dead axle

8-64. Where are the vehicle weight-supporting bearings in a full floating axle located?

1. At the inner end of the axle housing
2. On the outer end of the axle shaft
3. On the outer end of the axle housing
4. At the inner end of the axle shaft

8-65. Which of the following would cause noise in the rear axle assembly only when turning?

1. Faulty differential gears
2. Worn axle support bearings
3. Excessive backlash between the ring and pinion gears
4. Loose carrier bearings

8-66. Which of the following components must be removed from the axle assembly before the differential carrier can be withdrawn?

1. Wheels
2. Axles
3. Differential gears
4. Pinion shaft

8-67. Which of the following methods is used to determine if the thrust washers of a differential assembly are reusable?

1. Match the old thrust washers with new ones and see if they appear to be the same thickness
2. Measure the old thrust washers with a machinist's ruler
3. Check the old thrust washers with a micrometer

8-68. When either the pinion or bevel gear is damaged or shows signs of excessive wear, which of the following should you replace?

1. The worn or damaged part only
2. Both gears
3. The entire differential assembly

8-69. During reassembly of a differential assembly, why are the bearings "preloaded"?

1. To position the bearings in their races exactly as they will be when the vehicle is operating
2. To determine if the bearings' strength is sufficient to withstand heavy loads during operation
3. To prevent early bearing failure when the vehicle is returned to service
4. To keep from upsetting the wear pattern already established within the bearings' races

8-70. When reassembling any differential assembly, which of the following procedures should you use to insure that the pinion and bevel gears are adjusted properly?

1. Adjust backlash prior to preloading the pinion bearings
2. Adjust to allow only a slight free movement between the gears
3. Adjust so that no binding is present between the gears, then preload bearings
4. Adjust in accordance with the manufacturer's procedures

8-71. After setting the pinion depth in a differential assembly, which of the following must you determine prior to adjusting the backlash?

1. Amount of torque required to turn the pinion shaft
2. Amount of wear left in the pinion gear teeth
3. Whether or not the tooth contact pattern corresponds with the manufacturer's recommendations
4. Amount of warpage present in the bevel gear

8-72. Why are the axle shafts contained in steering axle assemblies replaced when they contain worn constant velocity universal joints?

1. Parts procurement time and cost are excessive
2. Individual parts are not available
3. The axle must be returned to the manufacturer for repair
4. Special tools required for repairing these axles are not available in the maintenance shop

8-73. Which of the following devices is used to adjust the steering knuckles on all wheel-drive vehicles?

1. Eccentric bolts
2. Adjusting nuts
3. Shims or spacers
4. Oversize bearings

8-74. When the steering knuckles are too tight, which of the following will result?

1. Shimmy and poor steering control
2. Hard steering at all times
3. Rapid failure of the axle universal joints
4. Abnormal front tire wear

8-75. Failure of a winch to operate is usually the result of a broken or damaged

1. shear pin
2. drive shaft
3. universal joint
4. PTO gear

Assignment 9

Automotive Chassis and Bodies

Textbook, NAVEDTRA 10644-G: Pages 257 - 299

Learning Objective: Identify automotive chassis and suspension components and their functions and maintenance requirements.

9-1. Which of the following requirements must be satisfied by the components of a vehicle's chassis?

1. Support the vehicle and its payload
2. Provide for directional control
3. Allow smooth operation over rough roads
4. All of the above

9-2. In vehicular frame construction, which of the following factors is the most important?

1. Speed and operating conditions
2. Steering and suspension requirements
3. Vehicle size and payload

9-3. Frames are NEVER used on vehicles which have a wheel base of less than 110 inches.

9-4. Why are gusset plates used in vehicle frame construction?

1. To reduce vibration
2. To add extra strength at joints
3. To support the radiator
4. To support power train units

9-5. Which of the following parts of a passenger car frame support most of the weight of the car body?

1. X-members and engine supports
2. Front and rear cross members
3. Right and left side members
4. Horizontal and T-members

9-6. The side members of many passenger vehicle frames are closer together in the front than in the rear in order to

1. allow the vehicle to make sharper turns
2. supply a more rigid support for the engine
3. supply a more rigid support for the front wheels
4. cut down vibration from the engine

9-7. All retractable bumpers return to their original position after an impact.

9-8. A vehicle's suspension system is designed to do which of the following?

1. To support the weight of the vehicle
2. To allow the vehicle to be driven with varying loads
3. To allow the vehicle to travel over various types of terrains without severe risk of damage to the vehicle
4. All of the above

9-9. Which of the following components add to the unsprung weight of a vehicle?

1. Wheels
2. Axles
3. Rims
4. All of the above

9-10. As a vehicle goes over a bump, its multiple leaf springs are held together by the

1. spring shackles
2. rebound clips
3. bumper blocks
4. clip plates

9-11. Why are the rear springs of some vehicles clamped under the axle?

1. To get better traction
2. To prevent single wheel traction
3. To lower the center of gravity
4. All of the above

9-12. The forward end of a leaf spring is attached to the frame by means of a

1. spring shackle
2. pin and bushing
3. U-bolt

9-13. What is the purpose of an auxiliary spring?

1. To offset the effect of a weak main spring
2. To prevent braking of the main spring
3. To eliminate the danger of overloading
4. To provide additional support for heavy loads

9-14. Which component in a bogie suspension system distributes the rear load evenly to the axles?

1. Spring
2. Cross shaft
3. Torque rod
4. Guide bracket

9-15. Which of the following suspension components prevents excessive flexing of coil springs on curves?

1. Stabilizer bar
2. Rubber bumper
3. Torsion bar

9-16. The purpose of a shock absorber is to do which of the following?

1. Regulate the spring rebounds
2. Prevent the spring from returning with a sudden jolt
3. Prevent the spring bounces from being transmitted to the vehicle's body
4. All of the above

9-17. You are trying to lubricate the spring shackles of a vehicle, but cannot get the grease to penetrate. Which of the following actions should you take to correct the condition?

1. Jack up the body to loosen the bearing surface
2. Heat the grease fitting
3. Use a wire to clean the grease fitting
4. Each of the above

9-18. What should you do when you find one damaged shock absorber on the rear of the vehicle?

1. Replace the damaged shock absorber
2. Replace both rear shock absorbers
3. Replace all shock absorbers on the vehicle
4. Install a coiled helper spring to aid the damaged shock absorber

9-19. Temporary repairs on a cracked frame are best accomplished by which of the following methods?

1. Gas welding
2. Arc welding
3. Fishplating
4. Heli-arc welding

Learning Objective: Indicate characteristics of tires and wheels and point out procedures for maintaining and repairing tires and wheels.

9-20. The strength of a tire is determined by which of the following factors?

1. Size of the tire's bead
2. Amount of rubber contained in the tire tread
3. Number, type, and arrangement of tire plies
4. Thickness of the tire's sidewalls

9-21. Which of the following types of belt material provides the best mileage and strength in belted tires?

1. Nylon
2. Rayon
3. Fiberglass
4. Steel

9-22. Before raising a light vehicle to remove a wheel, which of the following steps should you take?

1. Block the wheels on the other axle
2. Place the transmission lever in the proper position
3. Slightly loosen the lug nuts
4. All of the above

9-23. A safety stand or suitable blocks should be placed under the axle of a raised vehicle if work is to be performed while a wheel is removed.

9-24. On a vehicle with disk wheels, which of the following thread arrangements will hold dual wheels to the hub on the left side of the vehicle?

1. Left-hand threads on the outer nut only
2. Left-hand threads on both nuts
3. Right-hand threads on the outer nut only
4. Right-hand threads on both nuts

9-25. In a dual wheel system, where should the inner tire valve stem be located in relation to the outer tire valve stem?

1. 90°
2. 180°
3. 270°
4. 360°

9-26. For which of the following purposes should you use a tire spreader?

1. To replace the tire on the rim
2. To remove the tire from the rim
3. To allow easy inspection and maintenance of the inside of the tire
4. To prevent injury when inflating the tire

9-27. When removing a tire from the rim, the first thing you should do is to

1. break the tire bead loose from the rim
2. deflate the tire by removing the valve core
3. remove the valve stem on all tubeless tires
4. remove the side ring from the rim

9-28. If a tire bead fails to seat properly on the rim when inflated to the correct pressure, what should you do?

1. Tap the tire lightly with a hammer
2. Remove the tire and inspect the rim
3. Overinflate the tire until the bead seats
4. Discard the tire and wheel

9-29. When you use a hydraulic cylinder and shoe to break the bead of an earthmover's tire away from the rim, the shoe applies pressure directly to the

1. sidewall
2. rim
3. bead

9-30. The appropriate size of cold patching material needed to patch a 1/4-inch hole in a tire tube is

1. 1 inch
2. 1 1/2 inches
3. 1 3/4 inches
4. 2 inches

9-31. Which of the following actions should you take when applying a ready-built patch to the inside of a tire?

1. Place the patch so that the first ply of cords in the patch is running in the same direction as the cords in the tire
2. Press the patch in the middle before pressing the edges
3. Bend the patch before applying
4. Each of the above

9-32. Which of the following tire repair methods does NOT require you to remove the tire from the wheel?

1. Ready-built patch repairing
2. Built-up patch repairing
3. Plug repairing
4. Gun repairing

9-33. How often should the tires on a Navy vehicle be rotated?

1. Once a month
2. Twice a year
3. Every 3000 miles
4. Every 5000 miles

9-34. When rotating the tires on a vehicle equipped with a spare tire, you should place the left front tire

1. on the right rear
2. on the right front
3. on the left rear
4. in the spare tire position

9-35. When traction is NOT a factor, where should you install a new tire on a dual wheel vehicle?

1. On the front of the vehicle
2. On the outside rear dual
3. On the inside rear dual

9-36. Maximum tire life depends mainly on the following factors?

1. Regular rotation
2. Proper inflation
3. Operating conditions

9-37. What is the probable cause of an X-type break in the surface of a tire?

1. Underinflated when damaged
2. Overinflated when damaged
3. Out-of-alinement when damaged
4. Wrong size

9-38. Radial cracks on the outside of a tire indicate that the tire has been operated

1. with low air pressure
2. over rough terrain
3. while overinflated
4. at high speeds

9-39. If you were to mismatch dual tires, the larger tire would wear faster than the smaller tire.

9-40. If you have to replace a 7.75 tire, you could allow a diameter difference of

1. 1/8 inch
2. 1/4 inch
3. 3/8 inch
4. 1/2 inch

9-41. A tire which exceeds the designated size for a given dual wheel should always be mounted on the

1. inside of the dual wheels
2. outside of the dual wheels
3. operator side of the vehicle
4. front, with the original front tire moved to the rear dual wheel

9-42. The valves on the front wheels and on the inside dual wheels point away from the vehicle, whereas the valves of the outside dual wheels point toward the vehicle.

9-43. If a vehicle is to be operated at highway speeds, the wheels should be balanced in order to reduce which of the following conditions?

1. Tire wear
2. Vibration and shimmy
3. Rapid steering wear
4. All of the above

Learning Objective: Describe the various types of steering systems, indicate functions of their components, and point out procedures for maintaining steering systems.

9-44. Which of the following is an advantage of power steering?

1. The steering linkage is less complex
2. Power steering requires less maintenance
3. Less effort is required for turning
4. Power steering allows sharper turns

9-45. Which feature of the worm and roller steering gear provides a variable steering ratio when turning?

1. Shape of the worm gear
2. Angle between the worm and sector
3. Relative position of the worm and cross shaft

9-46. The oil flow within the hydraulic power assist steering system is directed by the

1. hydraulic pump
2. control valve
3. power cylinder
4. drag link

9-47. When no effort is applied to the steering wheel of a hydraulically assisted steering system, the spool valve is held in the center position by

1. springs
2. hydraulic pressure
3. internal friction
4. shims

9-48. Which of the following parts initiates reaction within a hydraulic steering system, resulting in no kickback at the steering wheel when the wheels are subjected to a shock load?

1. Pitman arm
2. Cam
3. Control valve
4. Valve spool

9-49. The control valve of the hydraulic steering system must be in what position to get the feeling of road sense?

1. In the left turn position
2. In the right turn position
3. In the center position

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9-50. Which of the following techniques is used to eliminate free play from a drag link?

1. Tightening the adjusting plug(s)
2. Adding shims to the pitman arm socket
3. Installing a stronger spring in the drag link
4. Replacing the drag link

9-51. A tie rod end is considered to be in good shape if an inspection indicates which of the following conditions?

1. It is difficult to move the ball in its socket
2. A slight amount of drag is present in the ball socket
3. The ball is free to turn in the socket
4. The ball is tight in the socket

9-52. When servicing a vehicle equipped with power steering, which of the following items should you check to insure proper operation?

1. Drive belt
2. Hoses and fittings
3. Fluid level
4. Each of the above

9-53. Pivot inclination, caster, camber, toe-in and toe-out are terms referred to collectively as

1. steering geometry
2. wheel alinement
3. steering angle
4. turning radius

9-54. How are the knuckle pivots tilted in order to obtain positive caster on the front wheels of an automobile?

1. To the right
2. To the left
3. Forward
4. Backward

9-55. To obtain positive camber, you must have the wheels closer together at the

1. top than at the bottom
2. front than at the rear
3. bottom than at the top
4. rear than at the front

9-56. Which of the following adjustments is used to balance the effect of camber?

1. Toe-out
2. Caster
3. Kingpin angle
4. Toe-in

9-57. Which of the following defects in the steering system of a vehicle can cause the steering wheel to have too much play?

1. Loose wheel bearings
2. A worn steering gear
3. Worn steering knuckle plates
4. Each of the above

9-58. If the steering wheel of a vehicle must be turned a full turn before the pitman arm moves, what part of the steering system probably needs adjustment or replacement?

1. A wheel bearing
2. The steering gear
3. The steering linkage
4. A knuckle plate

9-59. When the EO complains that his vehicle wanders, what should you check for?

1. Low tire pressure
2. Improper front wheel alinement
3. Tight or loose wheel and brake adjustments
4. All of the above

9-60. Troubles in the steering system and the alinement of the front wheels are NOT the only sources of improper steering. Which of the following defects can also cause a vehicle to steer improperly?

1. Defective shock absorbers
2. Sagging springs
3. Too little air in one or more tires
4. Each of the above

9-61. What should be the difference in degrees between the front wheels of a vehicle when tested on a floating turntable?

1. 1
2. 2
3. 3
4. 4

9-62. To adjust the toe-in of a vehicle, you must adjust the

1. drag link
2. steering knuckle arms
3. pitman arm
4. tie rod

9-63. How many tie rods are contained in the steering linkage of a vehicle equipped with independent front suspension?

1. One
2. Two
3. Three
4. Four

Learning Objective: Indicate procedures for repairing and refinishing automotive bodies.

9-64. What should be done when rust or corrosion starts to appear on the body of a vehicle?

1. Paint the entire vehicle
2. Cover the rust and corrosion with primer
3. Clean and paint only the affected areas
4. Replace the rusty or corroded panels

9-65. Nicks and scratches on the surface of body tools should be removed with

1. a file and sandpaper
2. a bench grinder
3. emery paper

9-66. Before trying to straighten a dented panel, which of the following steps should you take?

1. Sand any paint from the damaged section
2. Remove the damaged panel from the vehicle
3. Remove any dirt or undercoating

9-67. When performing body work, you should NEVER use the dolly block as a hammer.

9-68. When removing dents with the hammer and dolly, which of the following procedures should you follow?

1. Start your work at the point of impact
2. Try to remove as much of the dents as you can with a minimum of blows
3. Use a crown faced hammer for panels that are flat or slightly curved
4. Strike the metal lightly and rapidly, using a pulling action

9-69. If major body work is being performed, when should the decision be made concerning the replacement of a damaged panel?

1. Before any attempt is made to return the panel to its original position
2. After jacking the panel almost back to its original position
3. Only after the panel and its braces are removed from the vehicle

9-70. Spot welds used to hold new sheet metal in position are placed at intervals of approximately how many inches?

1. 1
2. 2
3. 1 1/2
4. 1/2

9-71. When using the disk sander, you should exercise care to prevent

1. burning the metal
2. removing excessive paint
3. stretching the metal
4. cutting through the sheetmetal

9-72. When preparing a vehicle for painting, which of the following grades of sandpaper should you use last?

1. Coarse
2. Medium
3. Fine

9-73. Before applying paint to a vehicle, you should wipe down the body with a lint free cloth soaked in

1. turpentine
2. solvent
3. paint thinner
4. gasoline

9-74. Applications of epoxy fillers in automotive body work should be limited to a thickness of

1. 1/8 inch
2. 1/4 inch
3. 3/8 inch
4. 1/2 inch

Assignment 10

Brakes

Textbook, NAVEDTRA 10644-G: Pages 300 - 330

Learning Objective: Identify components and functions of drum and disk brake systems and point out techniques of maintaining and repairing these systems.

10-1. When brake pedal pressure is released, which of the following hydraulic brake system components causes brake fluid to return to the master cylinder?

1. Master cylinder piston spring
2. Brake shoe return spring
3. Brake pedal return spring

10-2. Which of the following is an advantage of having a dual master cylinder in a hydraulic brake system?

1. It enables the brakes to be applied with less effort
2. There is less chance of the brakes malfunctioning
3. It causes the brake shoes to wear longer
4. It makes for a safer brake system

10-3. When reconditioning a master cylinder, what should you do if the bore is badly pitted or corroded?

1. Hone the cylinder
2. Install a sleeve in the bore
3. Machine the bore oversize
4. Discard the cylinder

10-4. Which of the following tools should you use to determine if a master cylinder bore is worn excessively?

1. Micrometer
2. Caliper
3. Feeler gage
4. Hole gage

10-5. Why should a master cylinder be bled on the workbench before it is installed on a vehicle?

1. To prevent getting dirt in the cylinder
2. To save time in bleeding the entire brake system
3. To conserve brake fluid

10-6. In a vehicle with a dual brake system, which of the following conditions would indicate that the rear brakes are inoperative?

1. The rear wheels slide when the brakes are applied
2. Excessive pedal pressure is required to operate the brakes
3. The warning light operates with each brake application
4. Vehicle stopping distance has increased greatly

10-7. When the brakes are applied on a vehicle equipped with full-floating brakes, the self-energizing action will affect both brake shoes.

10-8. Which of the following actions must occur before the self-adjusting brake mechanism will function?

1. The primary shoe must move away from the anchor pin
2. The adjusting mechanism must pivot on the secondary shoe
3. The secondary shoe must be forced against the anchor pin by the primary shoe
4. The adjusting mechanism must pivot on the primary shoe

10-9. The self-adjusting brake mechanism will NOT function while traveling forward. Why?

1. The override spring prevents movement of the adjusting lever
2. The lever return spring forces the adjusting lever away from the starwheel
3. The actuating link disengages the pivot during forward motion
4. The secondary shoe will not move away from the anchor pin

10-10. Full floating brakes can be manually adjusted by turning the

1. eccentric anchor pins
2. cam bolts
3. starwheel

10-11. Why should you install a wheel cylinder clamp before removing the brake shoes?

1. To facilitate removal of the shoe retracting springs
2. To hold the pistons in the wheel cylinder
3. To prevent loss of brake fluid should someone accidentally depress the brake pedal
4. To keep dirt out of the cylinder when cleaning the backing plate

10-12. Why are brake shoe retainers used with full floating brakes?

1. To insure correct shoe contact with the drum
2. To hold the shoes against the backing plate
3. To facilitate reassembly of the brakes on the backing plate
4. To prevent overadjustment by the self-adjusting mechanism

10-13. Should the rivet holes be enlarged in a brake shoe, what action should you take?

1. Install oversize rivets
2. Weld the holes closed and re-drill
3. Discard the brake shoe

10-14. When riveting the lining to a brake shoe, which of the following procedures should you use?

1. Start at one end of the lining and work toward the other
2. Rivet both ends, then work alternately toward the center of the lining
3. Start in the center and work alternately toward each end of the lining

10-15. Brake linings worn thin on one side of a brake shoe indicate that the drum is

1. scored
2. bell-shaped
3. out of round

10-16. Why should the brake shoes be arched when a brake drum has been machined?

1. To allow full shoe contact with the drum
2. To insure effective braking
3. To eliminate the need for frequent adjustment
4. All of the above

10-17. Telltale tabs are built into some disk brake shoes for the purpose of

1. notifying the vehicle operator that the lining is worn and needs replacement
2. allowing easy installation and removal from the caliper
3. preventing the shoes from coming out of the caliper during operation
4. identifying the type of lining material used on the shoes

10-18. Which of the following is an advantage of disk brakes over drum brakes?

1. Provide instant braking action
2. Do not fade when hot
3. Operate well with wet linings
4. Each of the above

10-19. The disk from a disk brake assembly will require machining when scored to a depth of

1. 0.005 in.
2. 0.010 in.
3. 0.015 in.

10-20. Why should the rust buildup at the outer edge of the disk be removed before new brake shoes are installed?

1. To insure full contact of the lining with the disk
2. To prevent overheating and warpage of the disk
3. To insure proper operation of the caliper assembly

10-21. Which of the following tools should you use to check a disk for runout?

1. Micrometer
2. Outside caliper
3. Thickness gage
4. Dial indicator

10-22. When replacing disk brake shoes, why should you force the caliper pistons into the bores of the caliper?

1. To determine if the pistons are free to move in the caliper
2. To allow easy removal of the shoes
3. To inspect for hydraulic leaks around the piston seal
4. To allow removal of the rust ridge on the disk

10-23. Which of the following procedures should you use to seat a set of new shoes in a disk brake assembly?

1. Apply the brakes lightly several times at speeds of 35 to 40 miles per hour
2. Use several heavy brake applications at speeds of 15 to 20 miles per hour
3. Apply the brakes heavily 3 or 4 times at speeds of 35 to 40 miles per hour
4. Use several light brake applications at speeds of 15 to 20 miles per hour

10-24. Which of the following defects is the most likely cause of soft, spongy action of the brake pedal in a hydraulic brake system?

1. Faulty pedal return springs
2. Sticking wheel cylinder pistons
3. Air trapped in the brake lines
4. A clogged master cylinder breather

10-25. When removing air from the hydraulic brake system, you should bleed one wheel cylinder at a time starting with the wheel cylinder located

1. nearest to the master cylinder
2. farthest from the master cylinder
3. on the left front
4. on the right front

10-26. After bleeding the brakes of a vehicle. the master cylinder fluid level should be

1. level with the top of the reservoir
2. within 1/4 inch of the top of the reservoir
3. within 1/2 inch of the top of the reservoir
4. within 3/4 inch of the top of the reservoir

10-27. When starting the engine, which of the following reactions, if any, will you notice at the brake pedal if the vacuum booster is functioning properly?

1. The pedal will tend to raise against foot pressure
2. The pedal will tend to fall away from foot pressure
3. The pedal will become firm
4. None of the above

10-28. The air-hydraulic power cylinder is made up of which of the following assemblies?

1. Master cylinder, compressed air cylinder, and slave cylinder
2. Slave cylinder, control valve, and master cylinder
3. Control valve, compressed air cylinder, and slave cylinder
4. Control valve, master cylinder, and compressed air cylinder

10-29. Forward movement of the piston in the compressed air cylinder is dependent upon

1. brake pedal pressure
2. hydraulic pressure
3. air pressure
4. spring pressure

10-30. When the brakes are partially applied, what positions will the poppets in the control valve of the air-hydraulic power cylinder assume?

1. Atmospheric poppet open, air pressure poppet closed
2. Atmospheric poppet closed, air pressure poppet closed
3. Atmospheric poppet open, air pressure poppet open
4. Atmospheric poppet closed, air pressure poppet open

10-31. When the brakes are fully applied, what positions will the poppets in the control valve of the air-hydraulic power cylinder assume?

1. Air pressure poppet closed, atmospheric poppet open
2. Air pressure poppet closed, atmospheric poppet closed
3. Air pressure poppet open, atmospheric poppet open
4. Air pressure poppet open, atmospheric poppet closed

10-32. What is the function of the governor in an air-brake system?

1. To control the pressure in the reservoir
2. To control the operating speed of the compressor
3. To control the slack adjustment of the brake chambers
4. To control the speed of operation of the brake system when the brake valve is operated

10-33. Under normal operating conditions, the lower valve in the type 0-1 governor of an air-brake system will be unseated when the air pressure in the reservoir

1. rises to 85 psi
2. rises to 105 psi
3. falls to 85 psi
4. falls below 105 psi

10-34. To decrease the pressure range in the type 0-1 governor, you may

1. add shims beneath the upper valve guide
2. remove shims from the upper valve guide
3. turn the adjusting screw counterclockwise
4. turn the adjusting screw to the left

10-35. Which of the following gages is used to accurately adjust the type 0-1 governor?

1. Thickness gage
2. Vacuum gage
3. Depth gage
4. Air pressure gage

10-36. At what pressure range, within the type D governor, will the air pressure allow the exhaust stem to close the exhaust valve and to open the inlet valve?

1. 80-85 psi
2. 90-95 psi
3. 100-105 psi
4. 110-115 psi

10-37. At what pressure will the spring loading within the governor overcome the developed force of the air pressure under the diaphragm?

1. 80-85 psi
2. 90-95 psi
3. 100-105 psi
4. 110-115 psi

10-38. To increase the pressure setting of the D-type governor, you must do which of the following?

1. Turn the adjusting nut clockwise
2. Turn the adjusting nut counterclockwise
3. Add shims to the inlet valve guide
4. Add shims to the outlet valve guide

10-39. The purpose of the unloader assembly is to

1. unload or stop compression in the compressor and to load or start compression
2. cool, store, and remove moisture from the air and give a smooth flow of air to the brake system
3. protect the brake against excessive pressures
4. control the air pressure that is delivered to the brake chambers

10-40. Which of the following components is used to cool, store, and remove moisture from the air and give a smooth flow of air to the brake system?

1. Unloader
2. Reservoir
3. Safety valve
4. Brake valve

10-41. Which of the following components is used to protect the brake system against excessive pressures?

1. Pressure gage
2. Reservoir
3. Safety valve
4. Brake valve

10-42. Which of the following components indicates the reservoir pressure?

1. Brake valve
2. Safety valve
3. Governor
4. Pressure gage

10-43. Which of the following components allows the air to flow from the reservoir to the brakes?

1. Safety valve
2. Brake valve
3. Pressure gage
4. Each of the above

10-44. In maintaining the treadle brake valve of textbook figure 10-32, you lubricate the roller and hinge periodically.

10-45. Which of the following lubricants is used on the internal parts of a brake valve disassembled for cleaning?

1. Engine oil
2. Chassis lube
3. Bearing grease
4. Vaseline

10-46. Which of the following components is designed to convert the energy of compressed air into mechanical force and motion?

1. Brake chamber
2. Brake valve
3. Brake cylinder
4. Each of the above

10-47. Which component provides a quick and easy way of adjusting air brakes to compensate for wear?

1. Brake camshaft
2. Slack adjuster
3. Adjusting screw
4. Each of the above

10-48. Which of the following valves is designed to exhaust brake chamber air pressure and speed up brake release of the air brake system?

1. Quick release valve
2. Treadle type brake valve
3. Safety valve
4. Pedal type brake valve

10-49. The exhaust port of the quick release valve on a vehicle equipped with air brakes opens when the

1. diaphragm is forced downward by the application of brake pedal pressure
2. diaphragm is in a holding position
3. air pressure above the diaphragm is increased
4. brake pedal pressure is released

10-50. Which of the following valves is interchangeable in mounting with the quick release valve?

1. Safety valve
2. Tractor protection valve
3. Relay emergency valve
4. Combined limiting and quick release valve

10-51. Which of the following valves functions as a set of remotely controlled cut-out cocks for normal or emergency air brake operations?

1. Relay valve
2. Tractor protection valve
3. Relay emergency valve
4. Safety valve

10-52. What is a purpose of the relay emergency valve in an air-brake system?

1. To speed up the application of trailer brakes
2. To speed up the releasing of trailer brakes
3. To apply the trailer brakes when the emergency line of the trailer is broken
4. Each of the above

10-53. What is a function of the relay emergency valve during normal operation of a tractor-trailer unit?

1. To supply air to the trailer
2. To automatically release the excess amount of air pressure from the trailer
3. To synchronize trailer service brake air pressure and tractor service brake air pressure
4. Each of the above

10-54. Which of the following valves will enable the EO to apply the trailer brakes independently of the tractor brakes?

1. Hand control brake valve on the tractor
2. Relay valve
3. Tractor protection valve
4. Combined-limiting and quick-release valve

10-55. What valve is used in an air line to make sure that the air passage goes in one direction?

1. Single check valve
2. Relay emergency valve
3. Safety valve

10-56. What is a purpose of the hoses and fittings used between the tractor and the trailer?

1. To provide a flexible air connection
2. To make connecting and disconnecting easier
3. To allow air from the tractor to be used for braking the trailer
4. Each of the above

10-57. The purpose of the dummy coupling is to

1. allow air to leave a unit while preventing dirt from entering
2. prevent dirt from entering unused air lines
3. increase air pressure in a certain area to speed up application and release of trailer brakes
4. conserve compressed air

10-58. Which of the following devices is used in storing unused hose?

1. Air hose fittings
2. Chain dummy couplings
3. Bracket-type dummy couplings
4. Each of the above

10-59. Whenever the air pressure is within the normal operating range, the low pressure warning indicator will

1. remain open
2. remain closed
3. open and close intermittently
4. begin to flash or buzz

10-60. The contacts on a stop light switch (an electro-pneumatic device) will close when subjected to a minimum air pressure of

1. 5 lb
2. 10 lb
3. 15 lb
4. 20 lb

10-61. To perform an operational test on air brakes, you should apply and release the brakes while observing for which of the following conditions?

1. Sluggish engagement or release
2. Equal application
3. Binding linkage and exhaust of units
4. Each of the above

10-62. If the brakes engage when the emergency line is removed from a charged trailer system, the emergency relay valve is functioning properly.

10-63. To test for leakage of various units within the air brake system, you should use

1. a thick mixture of soap suds
2. water
3. a very light-weight oil
4. any handy liquid

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Assignment 11

Construction Equipment

Textbook, NAVEDTRA 10644-G: Pages 331 - 383

Learning Objective: Indicate operational characteristics, component functions, and maintenance procedures of the hydraulic systems, power shift and automatic transmissions, and track and track frame assemblies common to heavy duty construction equipment.

11-1. If 50 pounds of force were applied to piston 1 of textbook figure 11-1, how much force would be applied to piston 2?

1. 25 lb
2. 50 lb
3. 75 lb
4. 100 lb

11-2. Why is the reservoir of a hydraulic system vented?

1. To prevent the loss of fluid
2. To allow the reservoir to breathe
3. To separate air from the fluid

11-3. In a hydraulic system, where would you normally find the strainer?

1. On the discharge side of the pump
2. In the reservoir or inlet line of the pump
3. Between the filter and reservoir
4. In the pressure relief line

11-4. The operating pressure within a hydraulic system is created by the

1. capacity of the pump
2. resistance encountered by the fluid
3. action of the relief valve
4. displacement of the pump

11-5. Of the following types of hydraulic pumps, which is used the most often on construction equipment?

1. Diaphragm
2. Vane
3. Gear
4. Piston

11-6. When used to describe a hydraulic pump, what does the term "fixed displacement" indicate?

1. The volume of fluid passed by the pump during each revolution will remain constant
2. Operation of the pump is limited by the maximum pressure in the system
3. The pump is designed to operate at a constant speed

11-7. Which of the following functions is performed by the valves in a hydraulic system?

1. Control pressure in the system
2. Direct the flow of fluid
3. Regulate the flow of fluid
4. Each of the above

11-8. Why is a relief valve used in a hydraulic system equipped with a positive displacement pump?

1. To keep pressure from rising above a maximum point
2. To direct fluid into the top of the hydraulic cylinder
3. To direct fluid into the bottom of the cylinder
4. To keep pressure from falling below a minimum point

11-9. In a basic hydraulic system, the control valve serves to

1. keep the pump operating at a constant rate
2. send fluid back to the reservoir when pressure becomes too great
3. regulate the speed and operation of hydraulic cylinders

11-10. Which of the following best describes the operation of the double-acting cylinder illustrated in textbook figure 11-8?

1. More force will be applied by the cylinder as it is extended
2. More force will be applied by the cylinder as it is retracted
3. The cylinder will apply equal force in either direction

11-11. In a hydraulic system, why is tubing preferred to pipe?

1. Less expensive
2. Easier to bend, cut, and fit
3. Easier to maintain
4. All of the above

11-12. Why is the inner layer of a hydraulic hose made of synthetic material?

1. To reduce resistance
2. To prevent deterioration
3. To protect the strength members

11-13. The number of strength members in a high pressure hydraulic hose is normally limited to

1. 5
2. 6
3. 3
4. 4

11-14. Why are accumulators used in some hydraulic systems?

1. To increase fluid capacity
2. To absorb and stabilize shock loads
3. To stabilize the amount of fluid pumped

11-15. Which of the following conditions could cause hydraulic filters to become clogged frequently between changes?

1. Defective bypass valve in the filter
2. Clogged strainer in the reservoir
3. Too much foreign matter in the reservoir
4. Badly worn hydraulic pump

11-16. Assume that the packing gland on a hydraulic cylinder is tightened evenly and then the ram is extended. What should you notice on the ram?

1. Only a slight film of oil
2. An absolutely dry surface
3. Only a small trickle of oil

11-17. An excessive amount of fluid leaking inside a hydraulic system will cause which of the following?

1. Overheating of the fluid
2. Slow operation
3. Loss of power
4. All of the above

11-18. When suspecting excessive internal leakage of a fluid, you should observe the operation of the hydraulic system for signs of

1. fluid loss after short periods of operation
2. creeping and drifting of hydraulically operated components
3. low fluid temperature after a few hours of operation
4. quick acting hydraulically operated components

11-19. Should a control valve be found to have an excessive amount of internal leakage, you should do which of the following?

1. Replace the valve
2. Install new valve seals
3. Repair the spool portion of the valve

11-20. If the piston seal in a double-acting cylinder is faulty, fluid will leak from the cylinder being tested through the

1. breather hole
2. cylinder packing
3. hose connection
4. piston poppet

11-21. When two hydraulic cylinders operate together, you should replace the seals in both cylinders even if only one is faulty to insure that

1. equipment downtime is kept to a minimum
2. both cylinders operate in the same manner
3. all the seals in the seal kit are used
4. the repaired cylinder does not fail prematurely

11-22. Which of the following conditions will cause the operation of a hydraulic system to be noisy and erratic?

1. Low fluid pressure in the system
2. A sticking relief valve
3. Air leaks in the suction lines
4. Faulty seals in the control valve

11-23. The pump of the fluid coupling is usually bolted directly to the

1. engine
2. transmission input shaft
3. planet carrier gear
4. ring rear

11-24. The turbine of the fluid coupling is connected to the

1. flywheel
2. transmission
3. crankshaft
4. clutch housing

11-25. What causes the turbine blades inside a fluid coupling to rotate?

1. Oil thrown by the pump
2. Clutch
3. Crankshaft
4. Flywheel

11-26. Which of the following components is necessary to make the fluid coupling perform as a torque multiplier?

1. Impeller
2. Turbine
3. Stator
4. Each of the above

11-27. A torque converter should have a small amount of slippage to prevent

1. overheating of the fluid
2. free wheeling at low speed
3. excessive internal pressure
4. stalling of the engine

11-28. The hydraulic torque converter automatically varies output to meet changing load requirements by doing which of the following?

1. Increasing torque while maintaining constant speed under changing load requirements
2. Increasing torque as load increases and speed decreases
3. Reducing torque as load increases and speed decreases

11-29. Why is fluid within the hydraulic torque converter pressurized?

1. To provide adequate lubrication
2. To cool the converter assembly
3. To supplement impeller pumping action
4. To reduce vacuum pockets in the converter

11-30. When the high-lo lever of the International Harvester (IH) power shift transmission is shifted; a sliding gear on the spline shaft meshes with gears on the

1. reverse clutch shaft
2. foreward clutch shaft
3. bevel pinion shaft
4. spline shaft

11-31. In the IH power shift transmission, which shaft is driven by the hi-lo gear?

1. Reverse clutch shaft
2. Foreward clutch shaft
3. Bevel pinion shaft
4. Spline shaft

11-32. Before shifting the hi-lo range lever in the IH power shift transmission, you must put the gearshift lever in neutral while the engine is running.

11-33. Which of the following components helps make up the planetary gear system?

1. Sun gear
2. Ring gear
3. Planetary carrier
4. Each of the above

11-34. Which of the following gears is the center gear in the planetary gear system?

1. Planet pinion
2. Ring gear
3. Sun gear
4. Planetary carrier

11-35. How many different ways can the plantary gear set be employed to either increase or decrease torque?

1. 6
2. 2
3. 8
4. 4

11-36. Which of the following hydraulically operated components are used in the automatic transmission to make it shift automatically?

1. Clutches and bands
2. Servos
3. Governors and valves
4. All of the above

11-37. The length of a track will gradually increase during normal use because of

1. stretching
2. wear on the track links
3. wear on the sprocket and idler
4. pin and bushing wear

11-38. Which of the following measurements are used to determine the wear of a track assembly?

1. Bushing diameter and track pitch
2. Pin diameter and track pitch
3. Link width and bushing diameter
4. Chain length and link width

11-39. How many track links should you measure across when checking for pin and internal bushing wear?

1. 5
2. 2
3. 3
4. 4

11-40. Which of the following means are used to aline the track frames on IH crawler tractors?

1. Thrust bearings
2. Shims
3. Wear plates
4. Eccentric support shafts

11-41. Which of the following track frame components maintain alinement of the track assembly as it passes over the track frame?

1. Track rollers
2. Guiding guards
3. Front idlers
4. Carrier rollers

11-42. To relieve tension on the track of a modern crawler tractor, you should do which of the following?

1. Back off the adjusting nut on the idler yoke
2. Loosen the vent screw on the track adjuster
3. Add shims in front of the recoil spring

11-43. If the track on a crawler tractor is too loose, it will have a tendency to do which of the following?

1. Fail to stay in alinement
2. Come off when the tractor is turned
3. Damage the carrier rollers
4. All of the above

11-44. The track and track frame should be inspected during each scheduled maintenance period for which of the following?

1. Abnormal wear and misalinement
2. Leaking seals and loose track shoes
3. Loose and missing parts
4. All of the above

Learning Objective: Identify the types and construction characteristics of wire rope and wire rope attachments, and indicate practices associated with their use, care, and handling.

11-45. Which of the following components represents the basic unit used in the construction of a wire rope?

1. Core
2. Strand
3. Wire

11-46. Which of the following pieces of information are given by the wire rope designation, 9/16 inch 6 x 19?

1. Rope diameter, number of strands and number of wires per strand
2. Core diameter, number of wires per strand and number of strands
3. Strand diameter, number of strands and number of wires per strand

11-47. Assume that you have four types of wire rope available for a job that requires wire rope of great flexibility. Which of the following types should you select if all of the wire ropes will provide adequate strength?

1. 6 x 7 fiber core
2. 6 x 19 independent wire rope core
3. 6 x 24 wire strand core
4. 6 x 37 fiber core

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When answering items 11-48 through 11-50, select from column B the wire and strand lay that is characteristic of the wire rope in column A.

	A. Wire Ropes	B. Wire and Strand Lays
11-48	Right regular lay	1. Wires right, strands right
11-49.	Left regular lay	
11-50.	Right lang lay	2. Wires left, strands left
		3. Wires right, strands left
		4. Wires left, strands right

11-51. What is the approximate safe working load, in tons, of a new 1-inch wire rope? (Use the NAVFAC formula.)

1. 1
2. 2
3. 3
4. 4

11-52. If a wire rope should form a loop, what action should you take?

1. Uncross the ends and push them apart
2. Cut out the loop
3. Pull it out by stretching one end of the rope
4. Coil the rope onto a drum

11-53. What is the largest size of 6 x 19 wire rope that you should use on a 10-inch sheave?

1. 1 in.
2. 1/2 in.
3. 5/8 in.
4. 3/4 in.

11-54. When preparing to cut a 1-inch wire rope, you should seize the rope on both sides of the cutting point using which of the following?

1. Two 1-inch seizings spaced 3 inches apart
2. Three 1-inch seizings spaced 2 inches apart
3. Three 2-inch seizings spaced 1 inch apart
4. Two 3-inch seizings spaced 1 inch apart

11-55. Under what conditions do you use a serving bar or iron to increase tension on the seizing wire when putting on the turns?

1. If the seizing is temporary or if the diameter of the wire rope is 1/2 inch
2. If the seizing is temporary or if the diameter of the wire rope is 1 inch
3. If the seizing is permanent or if the diameter of the wire rope is 1-1/2 inches
4. If the seizing is permanent or if the diameter of the wire rope is 1-5/8 inches or more

11-56. Assume that you have just installed a wedge socket on the end of a wire rope. With the bight completely closed, the bitter end should extend below the socket approximately

1. 2 inches
2. 4 inches
3. 6 inches
4. 8 inches

Learning Objective: Identify operational characteristics and service procedures applicable to heavy duty air compressors.

11-57. Which of the following pressure settings is normal for the governor on a heavy duty air compressor?

1. 95 psi
2. 100 psi
3. 105 psi
4. 110 psi

11-58. In the rotary compressor, the sliding vanes are held against the pump casing by

1. spring tension
2. oil pressure
3. air pressure
4. centrifugal force

11-59. In which phase of rotary compressor operation are the vanes farthest from the center of the rotor?

1. Intake
2. Discharge
3. Compression

11-60. In a diesel-driven air compressor, which of the following is a consequence of a faulty oil separator?

1. Compressor oil will contaminate the engine oil
2. Oil will be discharged with air from the compressor
3. The compressor will overheat from lack of lubrication

11-61. Which of the following types of air compressors is equipped with an intercooler?

1. Multistage reciprocating
2. Multistage rotary
3. Multistage screw
4. Single-stage screw

11-62. Why are aftercoolers used on some reciprocating air compressors?

1. To remove moisture from the air
2. To eliminate surges in air delivery
3. To prevent overheating of pneumatic tools
4. To reduce pressure in the distribution system

11-63. On a rotary air compressor, engine speed is regulated to correspond with which of the following?

1. Capacity of the compressor
2. Volume of air needed at the service valve
3. Discharge pressure of the compressor
4. Temperature of the air leaving the compressor

11-64. The demister used on the Worthington 600-cfm air compressor is for the purpose of

1. removing oil from the compressed air
2. removing water from the compressor oil
3. preventing moisture from entering the compressor
4. avoiding overlubrication of the compressor

11-65. When should you replace the air cleaner element on a Worthington 600-cfm compressor?

1. Each time the compressor oil is changed
2. After every 500 hours of operation
3. When inspection shows an accumulation of dust in the filter
4. When the red band is visible in the air cleaner service indicator

11-66. When there is no demand for air from the Worthington 600-cfm air compressor, which of the following conditions causes the engine to remain in the high idle position?

1. Broken speed control spring
2. Ruptured diaphragm in the speed control
3. High pressure in the receiver
4. Low engine temperature

11-67. On the Worthington 600-cfm air compressor how much air pressure must be in the receiver before the suction control valve will close?

1. 90 psi
2. 95 psi
3. 100 psi
4. 105 psi

11-68. Which of the following components of the vane-type compressor must be inspected for serviceability when the discharge air temperature becomes excessive?

1. Compressor housing only
2. Rotor vanes only
3. Oil orifices only
4. Compressor housing, rotor vanes, and oil orifices

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Assignment 12

Maintenance

Textbook, NAVEDTRA 10644-G: Pages 384 - 414

Learning Objective: Point out principles and techniques of administering the Civil Engineering Support Equipment maintenance system.

In items 12-1 and 12-2, select from column B the term that is defined in column A.

A. Definitions

12-1. To effect economy and dependability in the use of equipment and to insure continuity of operation

12-2. Care exercised and work performed to retain vehicles and equipment in safe and serviceable operating condition during their normal service life

B. Terms

1. Maintenance
2. Intermediate inspection
3. Navy Preventive Maintenance Program

12-3. Guidelines for the maintenance of equipment assigned to the Naval Construction Force are contained in which of the following NAVFAC publications?

1. P-280
2. P-300
3. P-315
4. P-404

12-4. Which of the following equipment services are included in organizational maintenance?

1. Lubrication and minor adjustments
2. Component rebuilding and major repairs
3. Major overhaul and restoration

12-5. The primary objective of preventive maintenance is to

1. insure that equipment is clean and serviceable
2. keep mechanics busy during slack periods
3. reduce equipment downtime and eliminate unnecessary repairs

12-6. What is the standard interval that NCF equipment is scheduled for preventive maintenance?

1. Once every 40 calendar days
2. Once every 40 working days
3. Once every six months

12-7. How many groups are used in PM scheduling?

1. 10
2. 25
3. 40
4. 60

12-8. Which of the following maintenance personnel can authorize changes to the PM schedule?

1. Maintenance supervisor
2. PM clerk
3. Shop supervisor
4. Each of the above

12-9. Which of the following items of information must a PM clerk have before establishing an annual PM inspection schedule?

1. Total number of vehicles and equipment assigned to the unit
2. Number of days to be worked each week by the mechanics
3. Number of mechanics assigned to each shop
4. Breakdown of the allowance by different types of equipment

12-10. How many times a day is an operator required to inspect an assigned item of CESE?

1. 1
2. 2
3. 3
4. 4

12-11. Unless the maintenance supervisor indicates otherwise, what type of PM inspection should be scheduled for a vehicle that has been driven 2200 miles since the last PM inspection?

1. "A"
2. "B"
3. "C"

12-12. How many times can a vehicle be given a type "A" PM inspection before a type "B" inspection is required?

1. 5
2. 2
3. 3
4. 4

12-13. How often are type "C" PM's performed on vehicles assigned to the Naval Construction Force?

1. Once every 6 months
2. Once a year
3. As often as the maintenance supervisor indicates
4. As often as two successive type "B" PM's occur

12-14. Why should deadlined vehicles be inspected on a regular basis?

1. To detect any cannibalization
2. To insure adequate preservation
3. To prevent deterioration
4. All of the above

12-15. What is the maximum amount of time that can be spent working on a vehicle before a shop repair order must be prepared?

1. 6 min
2. 12 min
3. 18 min
4. 24 min

12-16. When repairs are completed, which copy of the ERO is filed in the equipment history jacket?

1. White
2. Blue
3. Yellow
4. Green

12-17. When, if ever, should ERO's concerning major repairs be removed from equipment history jackets?

1. 90 days after the major repairs are accomplished
2. 2 years after the major repairs are accomplished
3. When the equipment is transferred
4. Never, they remain for the life of the equipment

12-18. How many individual shops are there in a typical NMCB maintenance organization?

1. 5
2. 2
3. 3
4. 4

12-19. Which of the following maintenance shops is responsible for small materials-handling equipment?

1. Automotive
2. Construction equipment
3. Support

12-20. In an NMCB, who has supervisory responsibility for maintenance performed on equipment away from the main shop facilities?

1. Emergency service supervisor
2. Heavy equipment shop supervisor
3. Support shop supervisor
4. Automotive shop supervisor

12-21. When equipment is in need of maintenance, who is responsible for determining the type of repair or services to be performed?

1. Operator
2. Shop inspector
3. Shop supervisor
4. Maintenance supervisor

12-22. Under normal conditions, how many times will an inspector inspect an item of equipment brought into the maintenance shop for repairs?

1. 1
2. 2
3. 3

12-23. Who is responsible for maintaining the direct turnover log (DTO) and repair parts summary sheets?

1. PM clerk
2. Cost control clerk
3. Maintenance supervisor
4. Technical librarian

12-24. How many mechanics, if any, are normally assigned to the repair parts storeroom?

1. 1
2. 2
3. 3
4. None

12-25. When an NMCB deploys, how many days should the initial supply of repair parts support operations?

1. 30
2. 60
3. 90
4. 120

In items 12-26 through 12-30, select from column B the level of repair parts support provided to the NCF unit in column A.

	A. NCF Units	B. Repair Parts Support Levels
12-26.	NMCB	1. D
12-27.	RNMCB	2. G
12-28.	NMCB (major detachment)	3. H
		4. O
12-29.	CBU	
12-30.	PHIBCB (major detachment)	

12-31. Repair parts for use on one make and model of equipment are called parts

1. peculiar
2. specific
3. consumable
4. common

12-32. To determine the APL(s) pertaining to a particular vehicle, which part of the COSAL should you refer to?

1. I
2. II
3. III

12-33. Which part of the COSAL provides a cross-reference between part numbers and stock numbers?

1. I
2. II
3. III

12-34. What criterion, if any, is used to determine how many technical manuals are provided to a unit for each type of vehicle assigned?

1. Vehicle population
2. Location of the maintenance facilities
3. Size of the maintenance facilities
4. None, each unit receives two copies

12-35. Which of the following forms should you use when requesting repair parts from the supply department?

1. NAVDOCKS 1949
2. NAVFAC 2421
3. NAVSUP 1250
4. DD form 1342

12-36. When filling out a NAVSUP 1250, why should you use the communication symbol for zero?

1. Because zero is not used in the NSN system
2. To distinguish it from the letter "O"
3. To allow computer scanning of the 1250's

12-37. What digits in a national stock number identify the country where the part was cataloged?

1. 1st, 2nd, 3rd, and 4th
2. 5th and 6th
3. 7th, 8th, and 9th
4. 10th, 11th, 12th, and 13th

12-38. After the requisition number is entered in block "B" of the NAVSUP 1250, which copy is returned to the cost control clerk?

1. White
2. Green
3. Red
4. Yellow

12-39. Which digit of a Julian date indicates the calendar year?

1. First
2. Second
3. Third
4. Fourth

12-40. How are the repair parts summary sheets filed by the cost clerk?

1. In numerical order by NSN number
2. By Julian date
3. In numerical order by PM groups
4. In numerical order by equipment codes

12-41. Who assigns the priority to all 1250's marked NIS or NC?

1. Requesting mechanic
2. Shop supervisor
3. Maintenance supervisor
4. Cost control clerk

12-42. Who is responsible for returning unused DTO parts to the supply department?

1. Cost control clerk
2. Floor mechanic
3. Shop supervisor
4. Shop inspector

Learning Objective: Indicate the correct procedures for using lubricants and lubricating equipment to service automotive and construction equipment.

12-43. Pressure fittings on automotive and construction equipment should be wiped clean before and after lubricating.

12-44. Which of the following actions is NOT appropriate to the use of a high pressure grease gun?

1. Moving the gun up, down, or sideways to remove it from a fitting
2. Pressing the gun coupler straight onto a clean fitting
3. Pulling the gun straight back to remove it from a fitting
4. Squeezing the gun's trigger slowly

12-45. You are lubricating the chassis of an automotive vehicle and find that some of the lubrication fittings are frozen. If the vehicle's weight has already been taken from the suspension system, what technique should you try in order to remedy the condition?

1. Treat each frozen fitting with penetrating oil
2. Blow out each frozen fitting with compressed air
3. Use a low-pressure hand oiler on each frozen fitting
4. Rock the vehicle while applying lubricant to each frozen fitting

12-46. The oil filter is designed to remove which of the following substances from the oil?

1. Metal chips and grit
2. Carbon and dust
3. Physical contaminants
4. All of the above

In items 12-47 through 12-49, select from column B the type of filter you would be servicing when using the procedure in column A.

	A. Procedures	B. Types of Filters
12-47.	Unscrew the filter from the base by hand	1. Throw-away
		2. Screw-on
12-48.	Remove the fastening bolt, lift off the cover or remove the filter shell	3. Replaceable element
		4. Replaceable cannister
12-49.	Detach the filter from its bracket and remove the brass fitting from its filter housing	

12-50. Which of the following actions is NOT necessary after you change the oil and oil filter in a vehicle?

1. Fill the crankcase to the full mark on the dip stick with the proper grade and weight of oil
2. Start and idle the engine
3. Inspect the filter for oil leaks; check the crankcase oil level and add oil to the full mark
4. After tightening the filter, back off 1/4 turn to prevent blockage of air

12-51. When an oil bath air cleaner is cleaned, which of the following is NOT an approved procedure?

1. Washing the filter element in a solvent
2. Removing the reservoir oil
3. Blowing excess solvent from the filter element with compressed air
4. Cleaning the reservoir

12-52. Which of the following steps is NOT necessary in servicing the wire gauze type air cleaner?

1. Wash and soak with oil
2. Oil the wire gauze with motor oil and allow the excess oil to drain
3. Empty the reservoir oil and clean the reservoir
4. Replace the element, cover, and wing nut

12-53. Which of the following actions is necessary to service the dry type carburetor air cleaner?

1. Wash the element with a very light weight oil
2. Oil the covering with motor oil
3. Tap the air cleaner to remove the dust or dirt
4. Blow the excess oil off the cleaner

12-54. Which of the following substances can be mixed with graphite and used to lubricate the shaft of the manifold heat control valve on an automotive engine?

1. Alcohol
2. Kerosene
3. Penetrating oil
4. Each of the above

12-55. Which of the following is a step in the procedure used to service the steering gear?

1. Clean around the fill plug on top of the steering gear housing before removing the fill plug
2. Check the oil level and add lubricant
3. Replace the fill plug
4. Each of the above

12-56. In addition to the intervals recommended by the manufacturer, wheel bearings should be serviced everytime the

1. brake drums are removed
2. brakes are adjusted
3. wheels are rotated

12-57. Which of the following front wheel bearing parts should NOT be washed in solvent?

1. Retaining nuts and washers
2. Ball bearings
3. Seals
4. Races

12-58. Assume that after installing a new cotter pin through the retaining nut you notice the wheel tends to drag. Which of the following could cause the wheel to do so?

1. Dragging brakes
2. Out-of-round brake drums or loose backing plates
3. Defective bearings or races
4. Each of the above

12-59. What parts, if any, of the single plate dry disk type clutch require periodic lubrication?

1. Clutch release and pedal shaft bearings
2. Lower and upper flywheel covers
3. Pedal and clutch shaft bearings
4. None

12-60. Assume that the lubricant of a conventional transmission in a truck which you are servicing has a tendency to foam when the transmission is in use. Which of the following steps should you take as part of the transmission service?

1. Drain the lubricant while it is warm and replace with fresh lubricant
2. Clean the area around the drain and fill plugs
3. Remove both the drain and the fill plugs
4. All of the above

12-61. When lubricating universal joints, what type of grease gun should you use?

1. High pressure, hand-operated
2. High pressure, air-operated
3. Low pressure

12-62. After how many miles of operation should you lubricate the shift detent lever on a passenger vehicle equipped with automatic transmission?

1. Every 1,000 miles
2. Every 1,500 miles
3. Every 2,500 miles
4. Every 3,500 miles

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